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November 1993

Radar Detection of Low-Altitude Targets in a Maritime Environment

Meteorological and Radar Data

Kenneth D. Anderson

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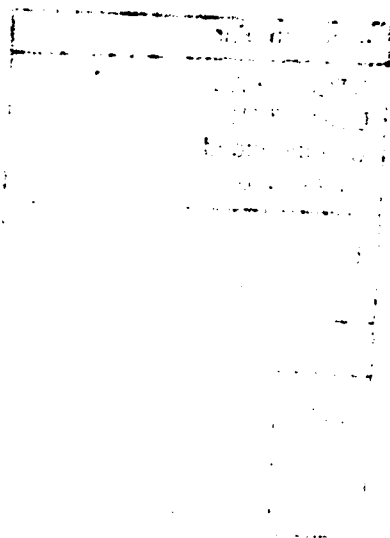
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ADMINISTRATIVE INFORMATION

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EXECUTIVE SUMMARY

OBJECTIVE

To assess the effects of the evaporation duct on the radar detection of low-altitude, small-radar-cross-section, sea-skimming missile targets.

RESULTS

A unique series of measurements clearly shows that the evaporation duct strongly affects the radar detection of low-altitude targets. Within the horizon, the duct may shift the location of the last interference null several kilometers in range, which may cause nondetection at ranges where detection is expected and detection at ranges where it is not. The evaporation duct may also reduce the signal strength at ranges near the last interference peak so that the detection of a low-altitude target may not be possible until the target is much closer.

At ranges beyond the last optical peak, the radar signal strength depends both on the surface layer and on the mixed layer. To accurately model propagation in this region, a knowledge of both surface layer and upper-air meteorology is required. An empirical model to merge the surface layer with the mixed layer has been developed. Additional studies and measurements, however, are needed to refine this model.

RECOMMENDATIONS

It is strongly recommended that effects from the boundary layer, especially evaporation ducting, be taken into consideration in the design and development of the next generation of radar and close-in weapon systems.

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INTRODUCTION

In recent years, instances have been noted where the maximum radar detection ranges of low-altitude targets over the ocean are less than expected. These instances of reduced detection ranges are associated with surface-based atmospheric ducting, particularly with evaporation ducting. Effects from these ducts are normally considered significant at long ranges [Hitney et al., 1985], but an analysis by Dockery clearly shows reduced detection capabilities for common duct heights, frequencies, and ranges [Dockery, 1988]. In addition to the well-known signal enhancement at ranges near and beyond the radio horizon, Dockery's modeling indicates that the evaporation duct affects the radar detection of small-sized, low-altitude targets within the horizon in two ways: First, it can shift the location of the last optical interference null several kilometers in range, which can cause nondetection at ranges where detection is expected. Second, it can substantially decrease signal levels near the last optical interference peak, which may explain the instances of greatly reduced detection ranges.

The work described here, an analytical and measurement effort to assess low-altitude, short-range propagation effects at X-band, has validated Dockery's modeling. All three features predicted by the model (enhanced signal beyond the horizon, range-shifted null locations, and reduced signal at the last interference peak) have been observed in a carefully controlled radar experiment. Although the essential features are observed in the radar data, discrepancies between the predicted and measured data warrant a closer examination of the meteorological measurements and surface layer theory.

In this report, the intent is to archive the data for future analyses. The companion report to this report [Anderson, 1993] describes the experiment and the results of the experiment in detail. The reader needing to know details of how the data were collected is referred to the companion report.

The graphs of the data are separated into three sections in this report. The first section, figures 1 to 48, is devoted to displays of measured propagation loss between the radar and the target. Figures 49 through 135 in the second section present the surface meteorological measurements (e.g., air temperature and sea temperature) as well as information on the location of the boat and geometry for each day of observations. The final section, figures 136 through 273, shows the upper-air modified refractivity and the temperature and humidity traces from the radiosonde launches made during the measurements. The first day of data is examined in each of these sections to familiarize the reader with what is shown in the figures. The data are presented in chronological order within each section.

Table 1 lists the days and times of the measurements. The first set of measurements was made on 11 October 1990; the last set on 14 February 1992. The first column of table 1 is labeled "Seq. No.," which is used as an abbreviation for Sequence Number. This number, ranging from 1 through 42, is used in the companion analysis as a shorthand notation to identify a particular measurement set. The times are local time and are either Pacific Daylight or Pacific Standard times, which are abbreviated as PDT or PST. The column labeled "Raob Launch Time" is the time identifying not only when a radiosonde was launched but a particular radiosonde that is thought to best describe the mixed-layer refractive gradient. The radar height (in meters above the ocean surface) is derived from the median tide height during the measurement period. The target height for both the inbound and outbound boat runs was originally set to 4.90 meters.

Table 1. Summary information for the 54 measurement sets.

Seq. No.	Date	Start Time	End Time	Raob Launch Time	Local Time Zone	Radar Height (m)	Target Height (m)	Refractive Condition
1	10/11/90	10:41	11:03	11:54	PDT	23.40	4.90	SBD
2	10/11/90	11:09	11:31	11:54	PDT	23.40	4.90	SBD
3	11/20/90	11:23	12:20	10:57	PST	22.90	4.90	NOR
4	11/20/90	12:31	13:13	10:57	PST	23.20	4.90	NOR
—	12/06/90	10:03	10:39	10:49	PST	22.70	4.90	STL
—	12/06/90	10:51	11:28	10:49	PST	22.60	4.90	STL
—	12/06/90	11:36	12:09	10:49	PST	22.60	4.90	STL
—	12/06/90	12:17	12:38	10:49	PST	22.60	4.90	STL
5	12/11/90	09:47	11:02	10:41	PST	23.90	4.90	ELV
6	12/11/90	11:54	12:31	11:17	PST	24.20	4.90	STL
7	12/18/90	09:58	10:39	10:32	PST	22.60	4.90	NOR
8	12/18/90	10:55	11:26	11:17	PST	22.80	4.90	NOR
—	01/16/91	10:27	11:18	11:49	PST	22.80	4.90	SBD
—	01/16/91	11:24	12:10	11:49	PST	23.20	4.90	SBD
9	01/30/91	09:46	10:20	10:36	PST	22.40	4.90	SBD
10	01/30/91	11:01	11:33	10:36	PST	22.90	4.90	SBD
—	01/30/91	11:39	11:56	10:36	PST	23.20	4.90	SBD
—	01/30/91	12:01	12:16	10:36	PST	23.40	4.90	SBD
11	01/30/91	12:23	12:54	10:36	PST	23.80	4.90	SBD
12	01/30/91	13:01	13:21	10:36	PST	24.10	4.90	SBD
13	02/13/91	10:06	10:42	09:56	PST	23.00	4.90	SBD
14	02/13/91	10:49	11:19	09:56	PST	23.30	4.90	SBD
15	03/06/91	10:17	11:36	10:06	PST	23.80	4.90	STL?
16	03/06/91	11:44	12:21	10:06	PST	23.60	4.90	STL?
17	03/11/91	13:12	14:30	13:03	PST	24.40	4.90	NOR
18	03/11/91	14:37	15:11	13:03	PST	24.20	4.90	NOR
19	03/14/91	10:15	11:33	10:06	PST	23.50	4.90	NOR
20	03/14/91	12:04	12:35	11:56	PST	24.10	4.90	NOR

(Contd)

Table 1. Continued.

Seq. No.	Date	Start Time	End Time	Raob Launch Time	Local Time Zone	Radar Height (m)	Target Height (m)	Refractive Condition
21	04/30/91	10:00	10:42	09:50	PDT	23.40	4.90	ELV
22	04/30/91	10:48	11:16	09:50	PDT	23.30	4.90	ELV
—	04/30/91	11:26	11:41	12:10	PDT	23.30	4.90	ELV
—	04/30/91	11:47	11:58	12:10	PDT	23.30	4.90	ELV
23	08/01/91	13:13	14:01	13:06	PDT	22.80	2.60	ELV
24	08/01/91	14:08	14:36	13:06	PDT	22.80	4.90	ELV
—	08/01/91	14:44	15:04	13:06	PDT	22.90	2.60	ELV
—	08/01/91	15:12	15:27	13:06	PDT	23.00	4.90	ELV
25	08/08/91	12:02	12:39	11:59	PDT	23.50	2.60	ELV
26	08/08/91	12:48	13:17	11:59	PDT	23.70	4.90	ELV
27	08/15/91	12:06	12:46	11:59	PDT	22.80	2.60	NOR
28	08/15/91	12:54	13:27	11:59	PDT	22.70	4.90	NOR
29	09/12/91	11:44	12:21	11:53	PDT	22.60	2.60	ELV
30	09/12/91	12:30	12:54	13:12	PDT	22.60	4.90	ELV
31	10/10/91	12:04	13:01	11:54	PDT	22.70	2.60	STL
32	10/10/91	13:09	13:44	11:54	PDT	23.00	4.90	STL
33	10/24/91	13:05	14:11	13:01	PDT	23.60	2.60	NOR
34	10/24/91	14:17	14:49	13:41	PDT	24.10	4.90	NOR
35	12/05/91	12:06	12:48	12:02	PST	23.30	2.60	ELV
36	12/05/91	13:54	14:27	14:39	PST	24.30	4.90	SBD
37	12/12/91	10:37	11:05	10:35	PST	23.20	2.60	ELV
38	12/12/91	11:20	11:42	11:17	PST	23.10	4.90	ELV
39	01/31/92	10:32	11:05	10:07	PST	23.60	2.60	STL
40	01/31/92	11:12	11:58	11:40	PST	24.00	4.90	STL
41	02/14/92	10:04	10:46	09:05	PST	24.10	2.60	NOR
42	02/14/92	11:07	11:34	11:03	PST	24.40	4.90	NOR

Starting with the outbound run of 1 August 1991, the aft facing corner reflector was lowered to 2.60 meters above the water. The rightmost column indicates the dominant refractive condition in the boundary layer. The four conditions are described by three-letter abbreviations. First, SBD implies a surface-based duct from an elevated layer. Second, NOR signifies a normal or standard atmospheric condition. Third, STL is an abbreviation for a surface (or near surface) trapping layer (the question mark on the 6 March 1991 measurements is an expression of uncertainty in the declaration of STL for this day). Lastly, ELV indicates an elevated duct. The distribution of refractive conditions is fairly uniform; 15 sets of measurements were made in refractive conditions best described as influenced by an elevated trapping layer; 14 sets were made during surface-based-duct (from elevated layers) and normal (near standard) conditions; and 11 sets were made during refractive conditions dominated by a surface trapping layer.

PROPAGATION LOSS VERSUS RANGE

Figure 1 is a plot of the propagation loss between the radar and the target for the first set of measurements made on 11 October 1990 between 10:41 and 11:03 PDT. The crosses on this plot indicate the measured propagation loss between the radar and the target. The solid line, the estimate of propagation loss in the presence of a standard atmosphere, is included as a reference. At ranges between about 7 and 15 km, the measured propagation loss is consistently greater than the loss predicted for a standard atmosphere. For a propagation loss threshold of 130 dB, the radar, in a standard atmosphere, is predicted to detect this target at a range of 13.5 km; the measurements indicate that the 130 dB threshold is actually at a range of 12.5 km—about an 8% reduction in detection range. The evaporation duct effect reducing signal strength near the last optical interference peak (at about 9 km in a standard atmosphere) is clearly evident and confirms Dockery's analysis. A shift in the last interference null location (at about 7 km in a standard atmosphere), while not as clear as the signal strength reduction, appears to be present and lends credence to the validation of the model.

SURFACE METEOROLOGICAL MEASUREMENTS

The meteorological and radar measurements for the first measurement period (11 October 1990) are summarized in figures 55 through 58. The data plotted in these figures are derived from averages or, for some data (target range and propagation loss) the median, in 1-minute time intervals. Figure 55 shows the range from the radar to the boat (in kilometers), and the surface meteorological measurements made on the boat, all plotted versus time. The wind speed (second plot from the top) is linearly interpolated from points in time when the boat was stopped and the wind velocity measured by a hand-held anemometer. The relative humidity, air temperature, and sea temperature (from the probes about 20 cm below the surface) are the data recorded by the computer controller. These data are minute averages of samples taken every 10 seconds. The humidity and sea temperature traces are reasonably repeatable for both the outbound and inbound runs, which indicates a range-varying meteorological environment and not a temporal-varying environment. The air temperature trace, particularly from about 1115 to 1130, has what appears to be considerable noise superimposed on the trace. The actual meteorological data used in the propagation model were derived from these curves but with careful analysis. Figure 56 is the surface meteorological data recorded at the F35 site (next to the radar). There are two sea temperature traces (from the two infrared sensors looking into the surf zone) and an additional plot of wind direction, which can be used to determine if the meteorological measurements at

F35 are contaminated by air flow from the land. Figure 57 shows the range from the radar to the boat, the evaporation duct height (calculated from the Jeske method) observed at the radar site and at the boat, and the air-sea temperature difference, again, at the radar site and at the boat.

At the start of the measurements, the boat observations indicate a thermally stable condition (air warmer than the sea), whereas the radar site observations indicate a moderate thermally unstable condition (air cooler than the sea). Shortly after 1030, both the boat, which was proceeding outbound, and the F35 site measurements indicate thermally unstable conditions. At 1041, the boat proceeded on an outbound run; at 1103, the boat reached its maximum range (for this run) and additional meteorological measurements were made. At 1109, the boat began its inbound run and completed this leg at 1131. The air-sea temperature difference as measured on the boat seems to be fairly repeatable in range, indicating that thermal stability varied more with range than in time. Between 1030 and 1130, the wind direction (measured at F35) was fairly consistent, coming from about due south, indicating that the measurements are (probably) representative of over-water conditions. The wind speed, measured at F35, was also fairly constant over this time interval; averaging about 6 knots.

Figure 58 shows the range from the radar to the boat, the azimuth bearing of the boat's position from the radar, the median propagation loss (in decibels) between the radar and the boat, the target height above the surface (4.9 meters), and finally, the radar height above the water. The slight change in the radar height is due to tidal action. The propagation loss measurements for the last outbound and inbound runs (from about 1150 to 1245) are unreliable. Unfortunately, a set of radar control circuits was changed between the first inbound run and the last outbound run, and this change was not recorded in the experiment log book. The gain of the radar appears to be about 6 dB higher in the latter measurements, but the actual value of gain or adjustment is unknown and unrecoverable. The last two runs (outbound and inbound) for this day are not used in the analysis for this reason.

UPPER-AIR METEOROLOGICAL MEASUREMENTS

Figure 143 is a plot of the modified refractivity (M units) versus height for the radiosonde that was launched on 11 October 1990 at 1154 PDT. The launch site was near the radar. Values of M (M is computed using the reported temperature, humidity, and pressure data from the radiosonde) are shown in this figure as open circles. The refractive profile, listed in figure 144, is derived from an analyst's interpretation of the data and is shown in this figure as the solid line. The "bulge" in refractivity near the surface is ignored because it is thought to be due to orographic and land heating effects, which are probably not representative of conditions over the water. Figure 143 shows a moderate-to-strong surface-based duct from an elevated trapping layer (SBD conditions). The base of the trapping layer is at 197 meters and, at this height, should not have a significant effect on propagation between the radar (height about 23.5 meters) and the target (height about 4.9 meters) for the ranges of interest. Figures 145 and 146 are the relative humidity and the air temperature traces recorded as the balloon ascended.

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- Dockery, G. D., "Propagation Fade Characteristics in Low-Altitude Surface Ducts," The Johns Hopkins University/Applied Physics Laboratory, Technical Report, Task 3-1-19, October 20, 1988.
- Hitney, H. V., J. H. Richter, R. A. Pappert, K. D. Anderson, and G. B. Baumgartner, Jr., "Tropospheric Radio Propagation Assessment," *Proc. IEEE*, vol. 73, pp. 265-285, February 1985.

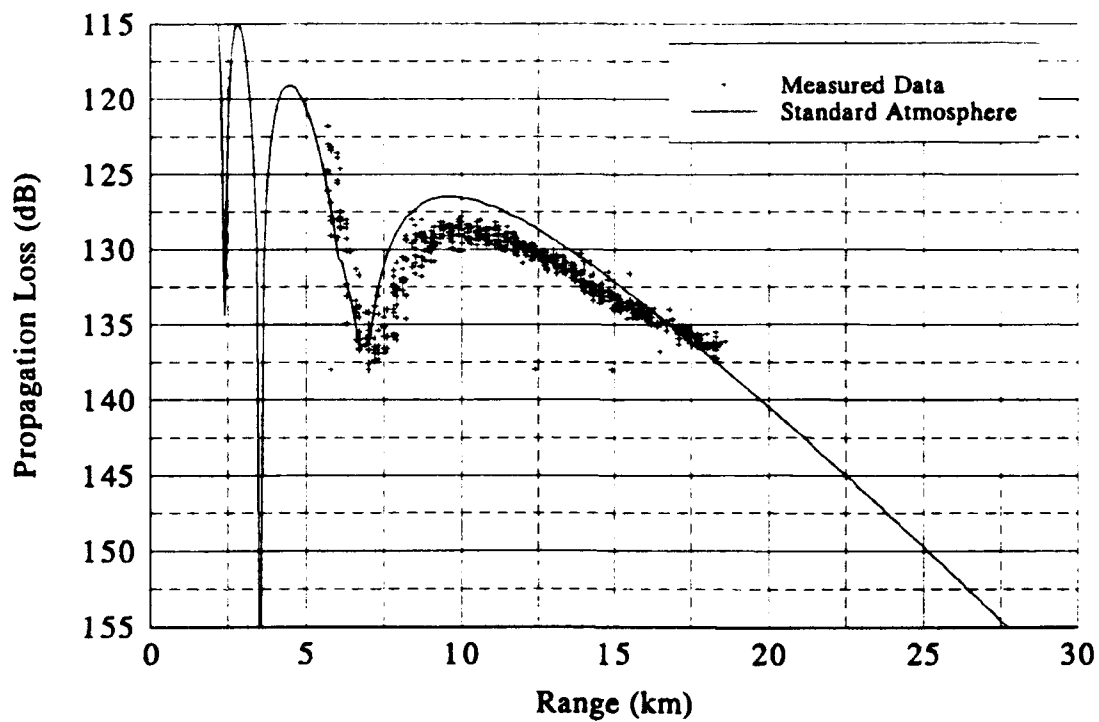


Figure 1. Propagation loss versus range measured on 10/11/90 from 10:41 to 11:03 PDT; target height, 4.9 m.

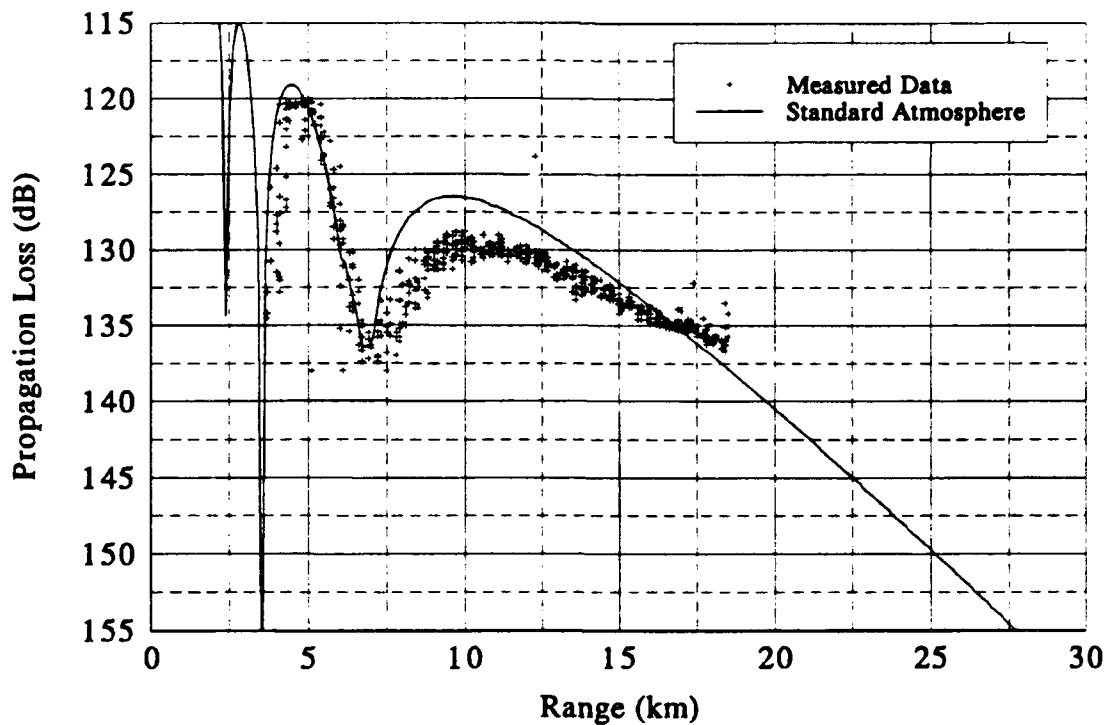


Figure 2. Propagation loss versus range measured on 10/11/90 from 11:09 to 11:31 PDT; target height, 4.9 m.

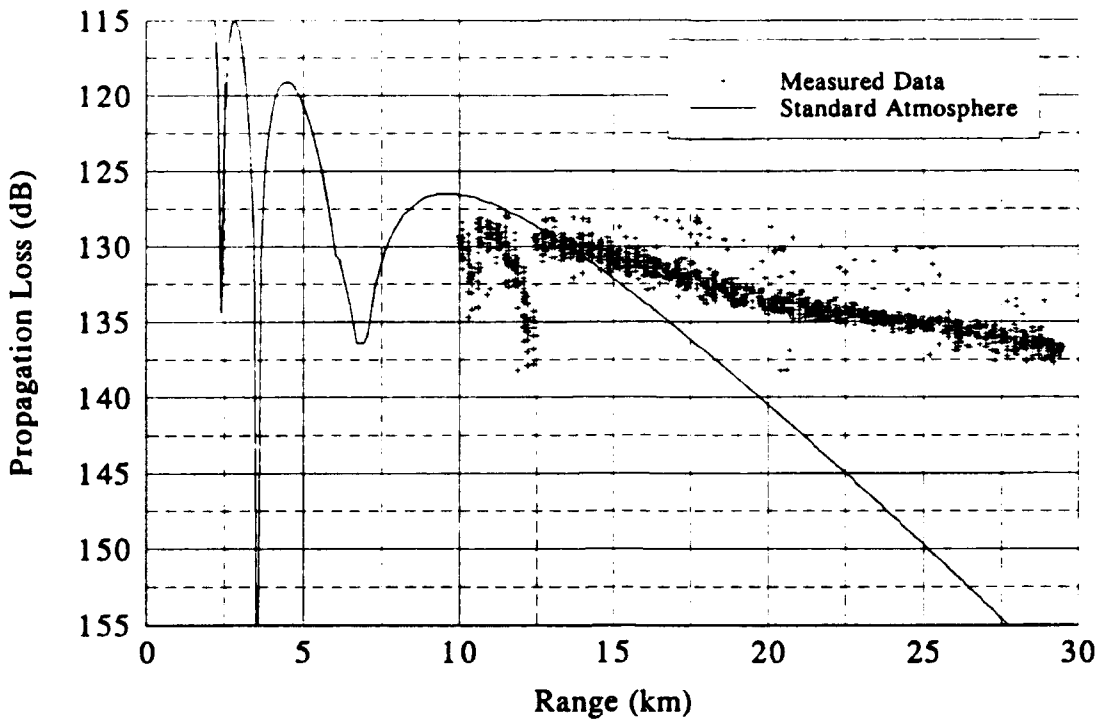


Figure 3. Propagation loss versus range measured on 11/20/90 from 11:23 to 12:20 PST; target height 4.9 m.

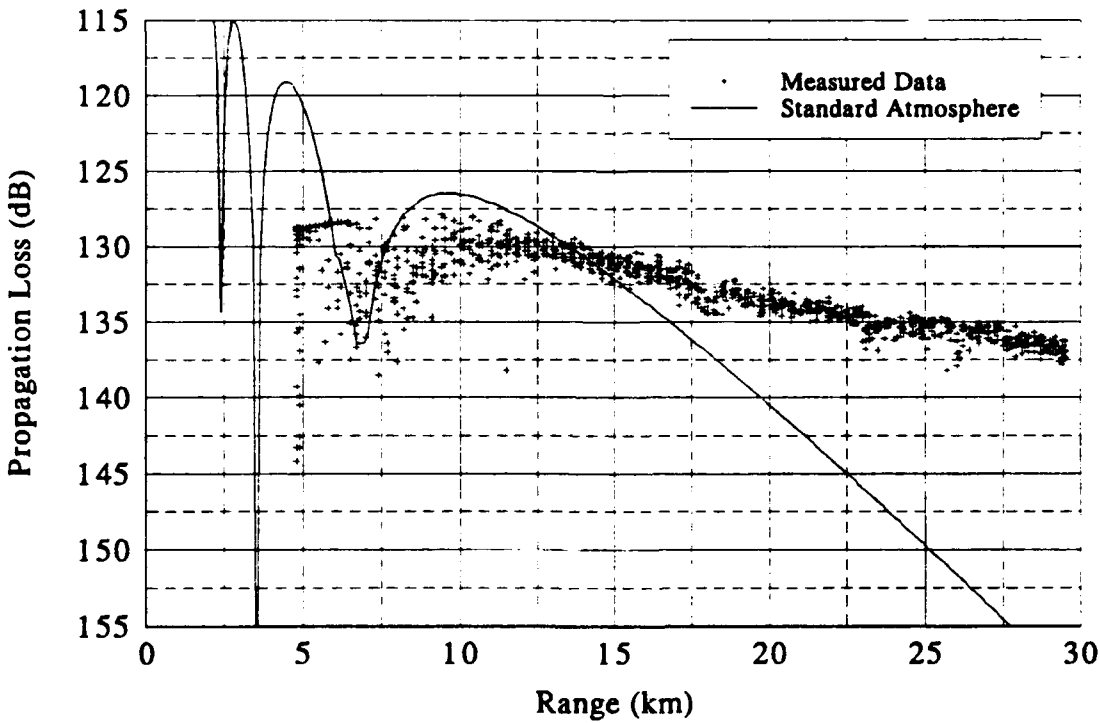


Figure 4. Propagation loss versus range measured on 11/20/90 from 12:31 to 13:13 PST; target height 4.9 m.

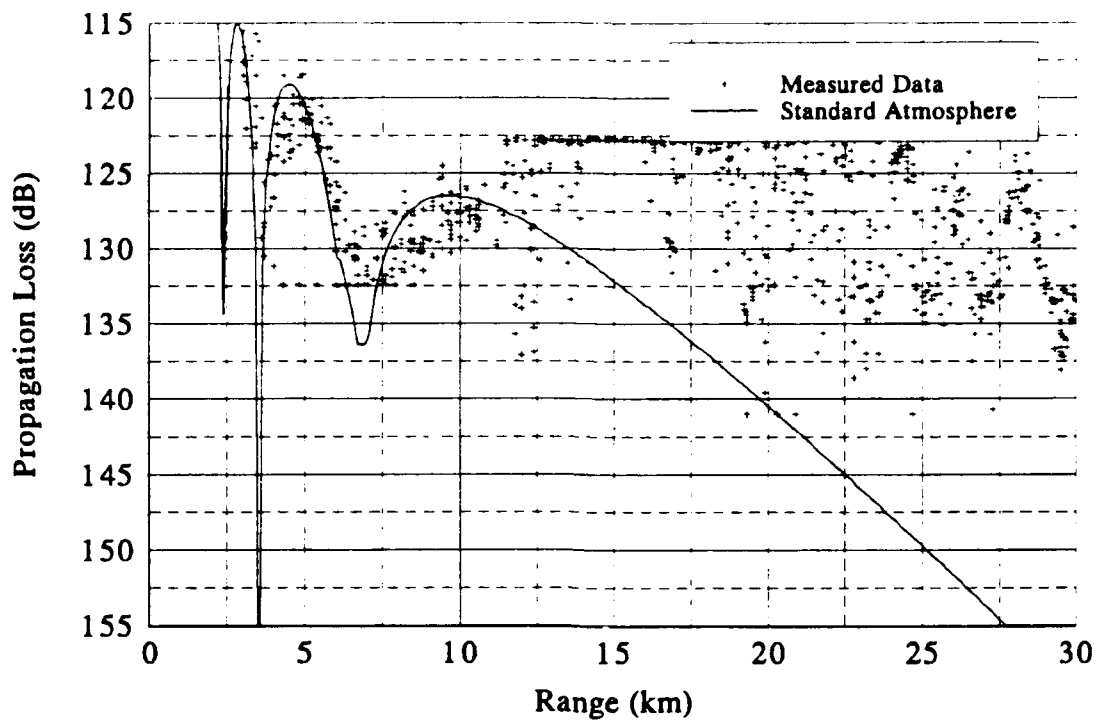


Figure 5. Propagation loss versus range measured on 12/06/90 from 10:03 to 10:39 PST; target height 4.9 m.

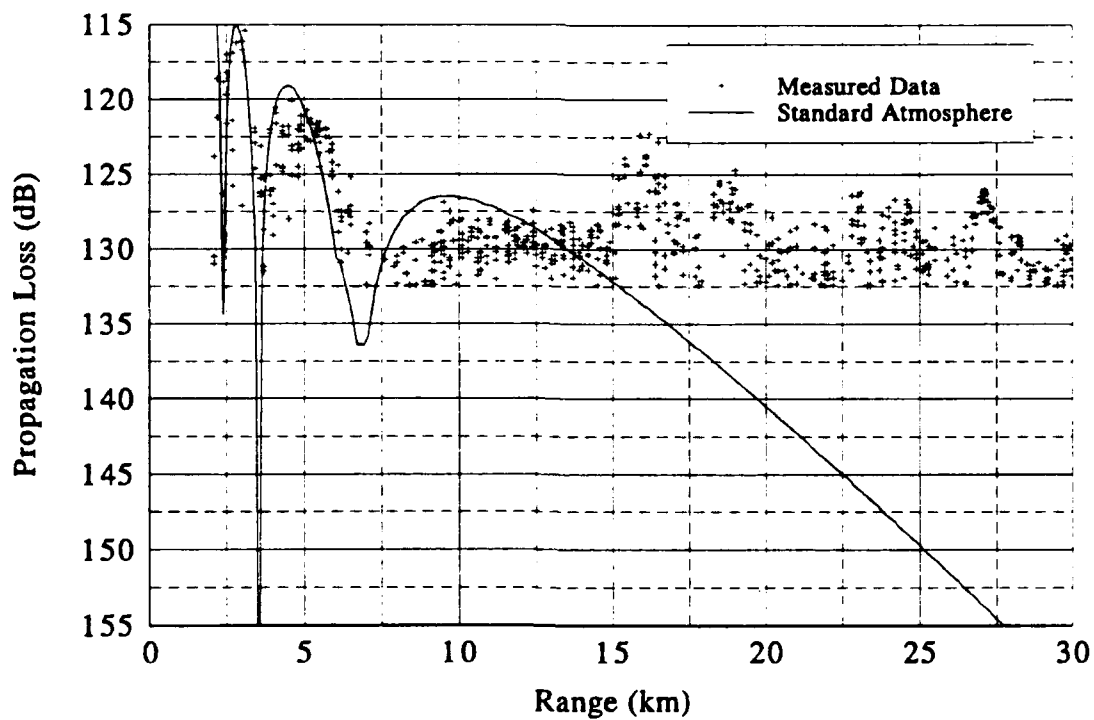


Figure 6. Propagation loss versus range measured on 12/06/90 from 10:51 to 11:28 PST; target height 4.9 m.

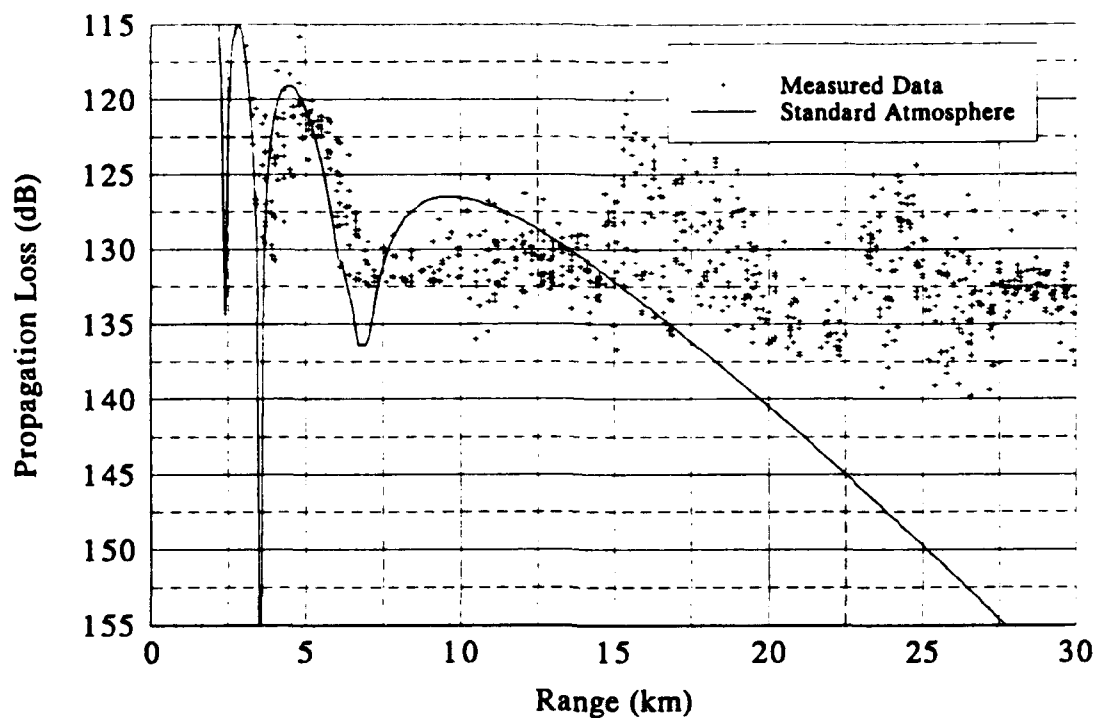


Figure 7. Propagation loss versus range measured on 12/06/90 from 11:36 to 12:09 PST; target height 4.9 m.

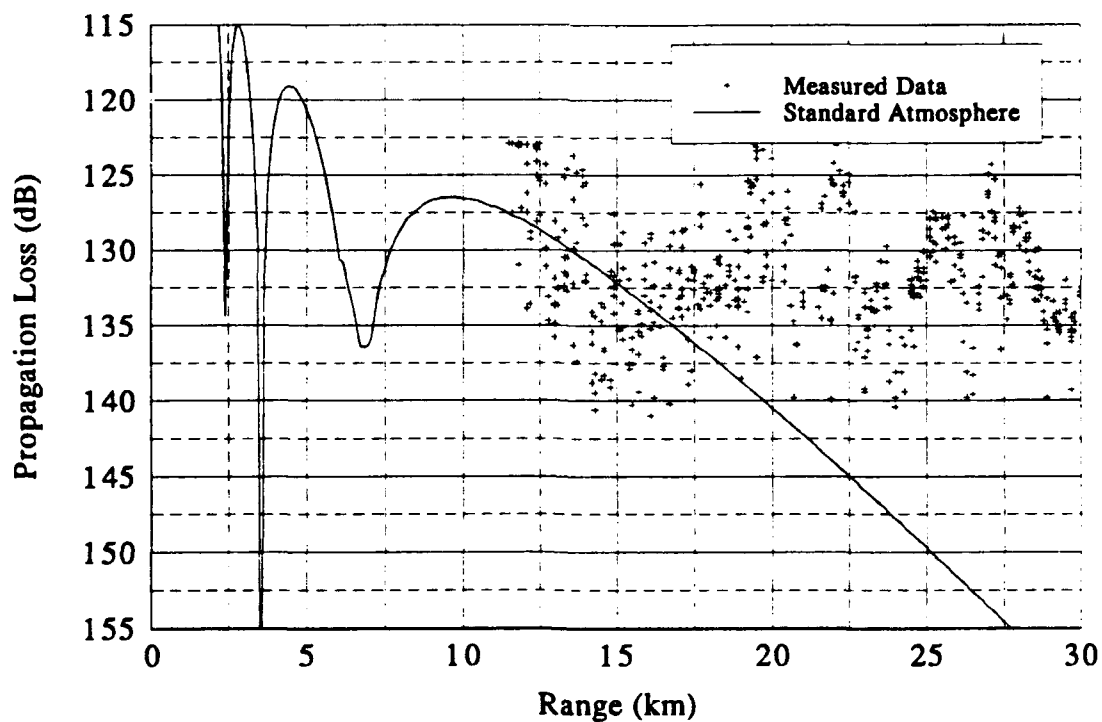


Figure 8. Propagation loss versus range measured on 12/06/90 from 12:17 to 12:38 PST; target height 4.9 m.

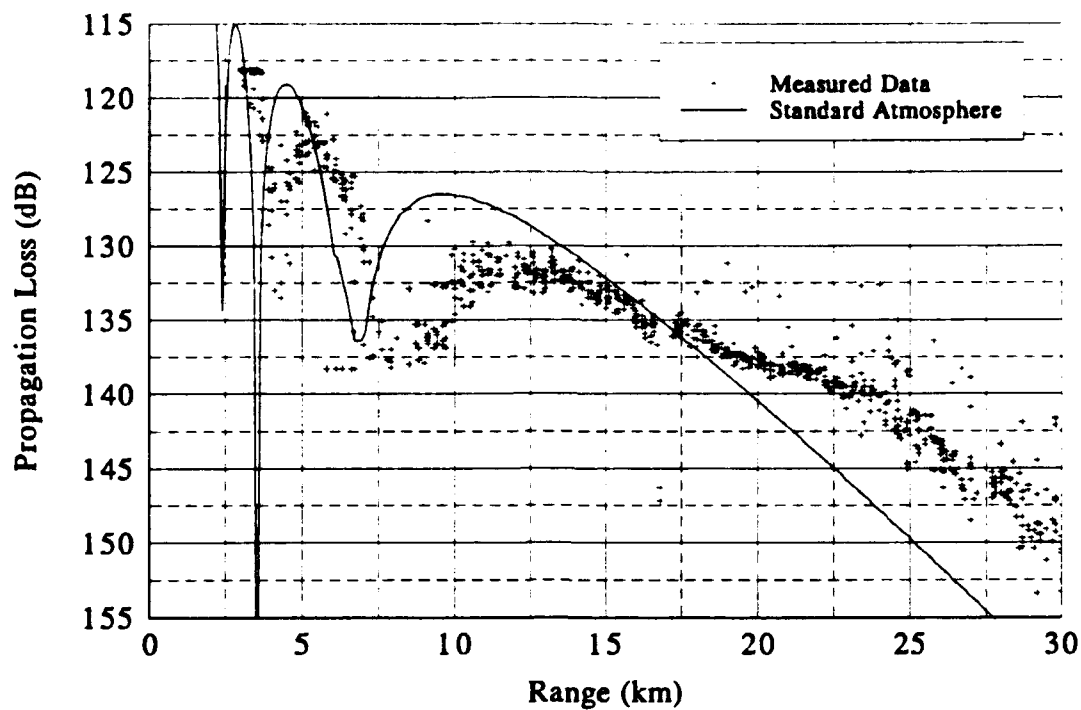


Figure 9. Propagation loss versus range measured on 12/11/90 from 09:47 to 11:02 PST; target height 4.9 m.

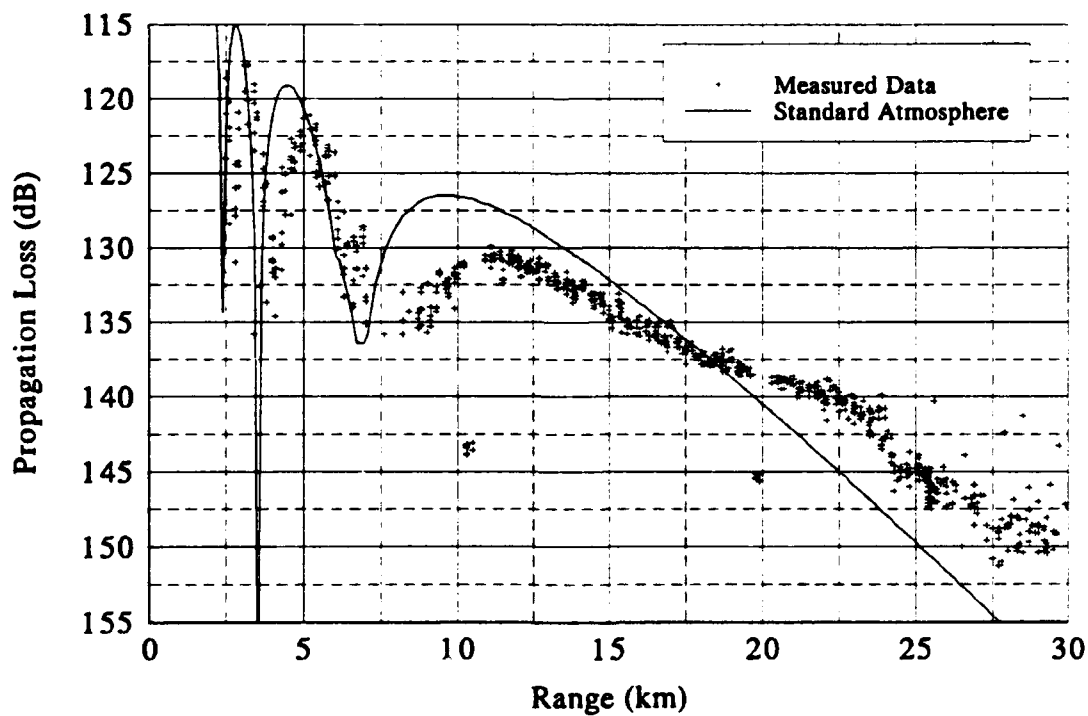


Figure 10. Propagation loss versus range measured on 12/11/90 from 11:54 to 12:31 PST; target height 4.9 m.

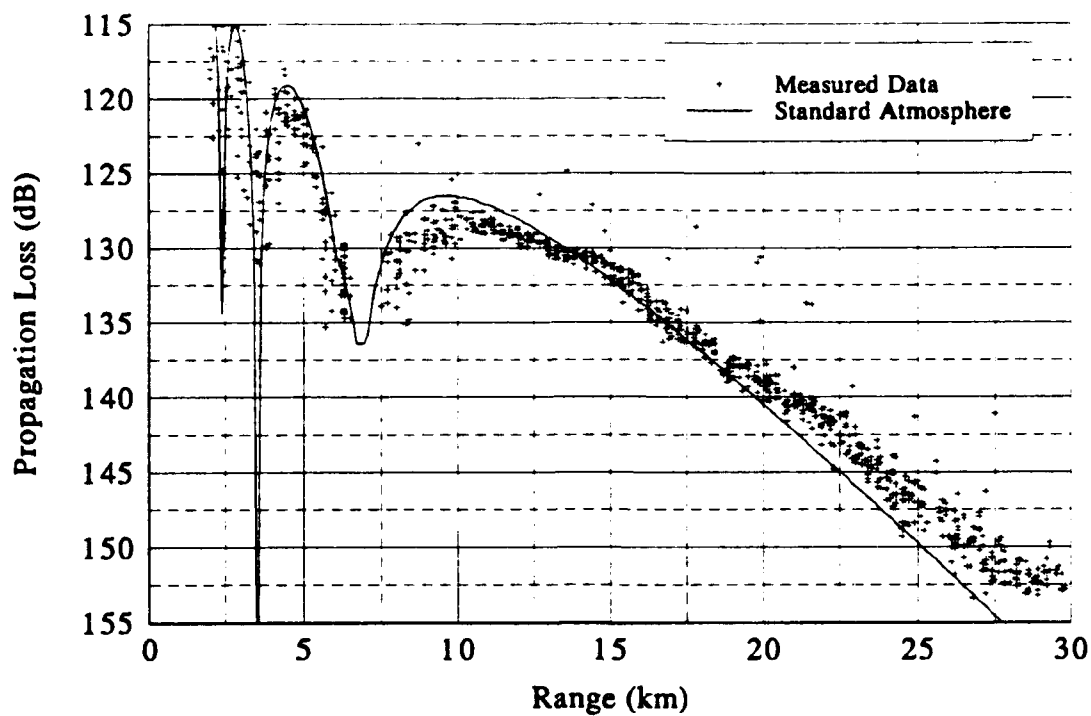


Figure 11. Propagation loss versus range measured on 12/18/90 from 09:58 to 10:39 PST; target height 4.9 m.

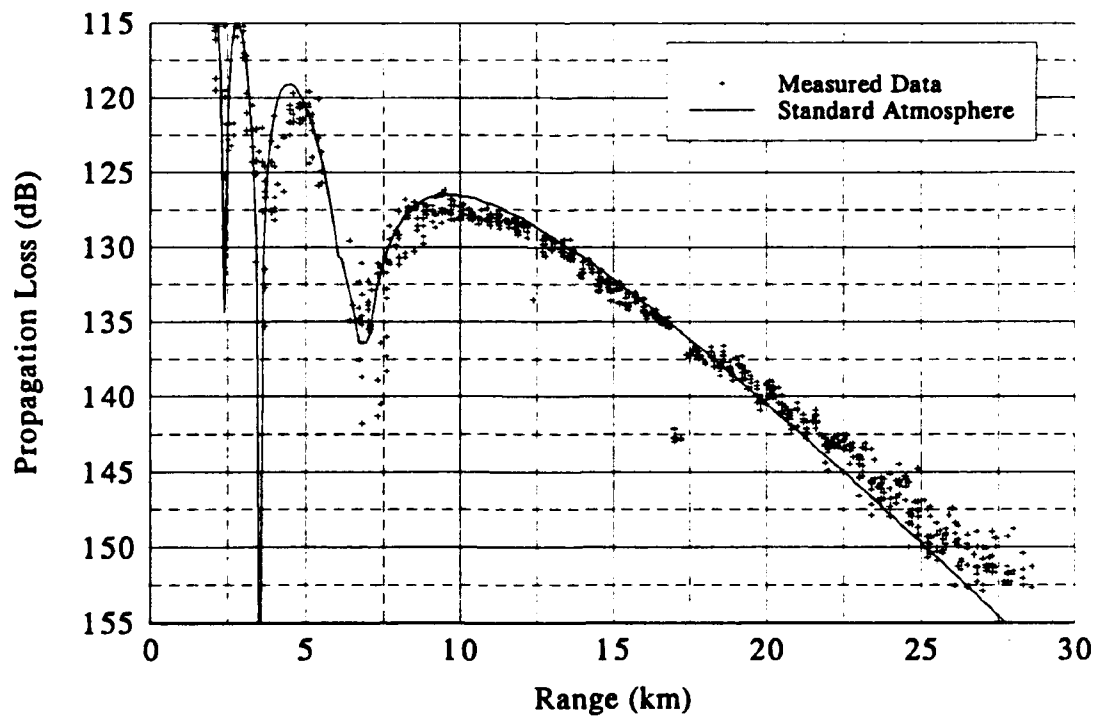


Figure 12. Propagation loss versus range measured on 12/18/90 from 10:55 to 11:26 PST; target height 4.9 m.

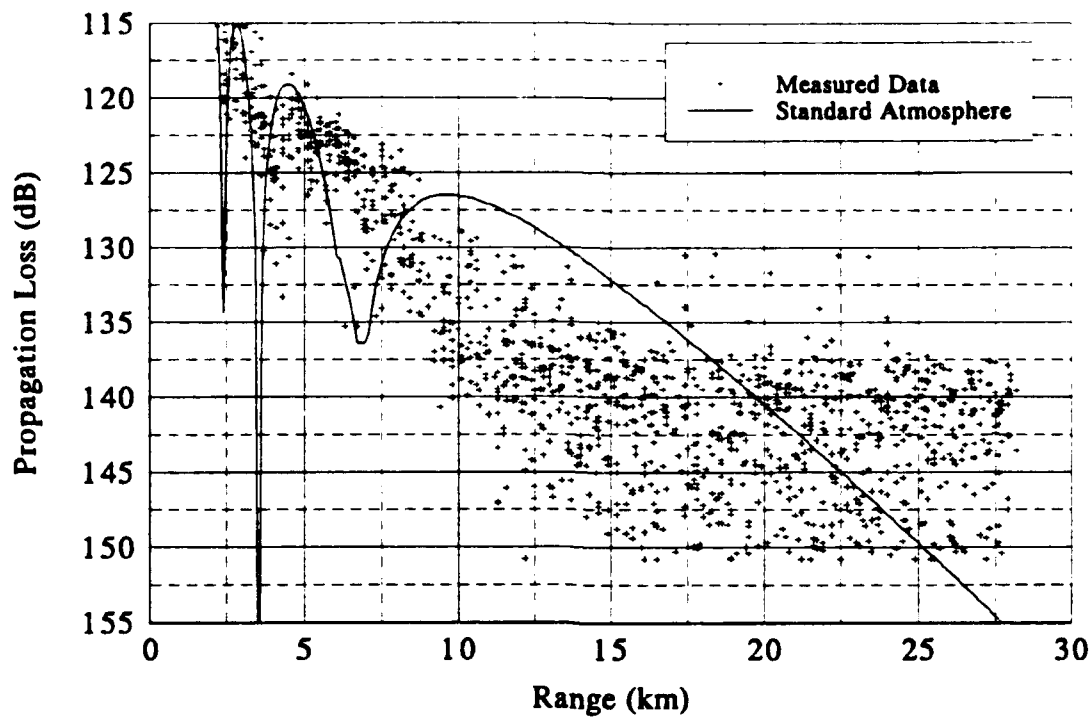


Figure 13. Propagation loss versus range measured on 01/16/91 from 10:27 to 11:18 PST; target height 4.9 m.

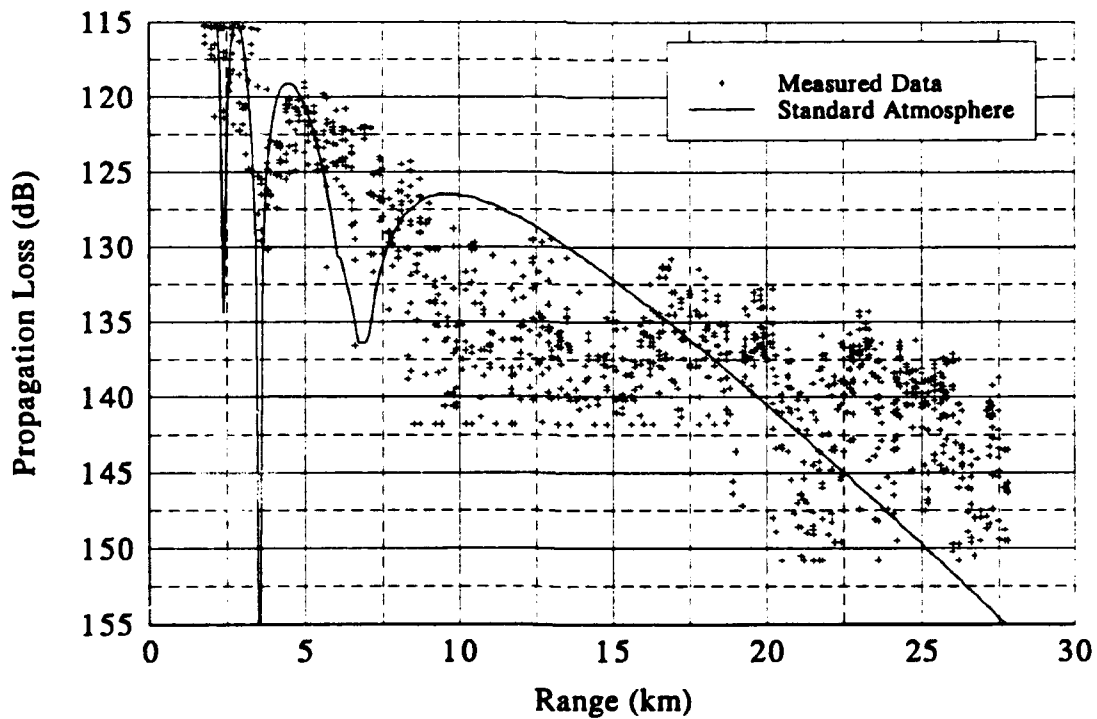


Figure 14. Propagation loss versus range measured on 01/16/91 from 11:24 to 12:10 PST; target height 4.9 m.

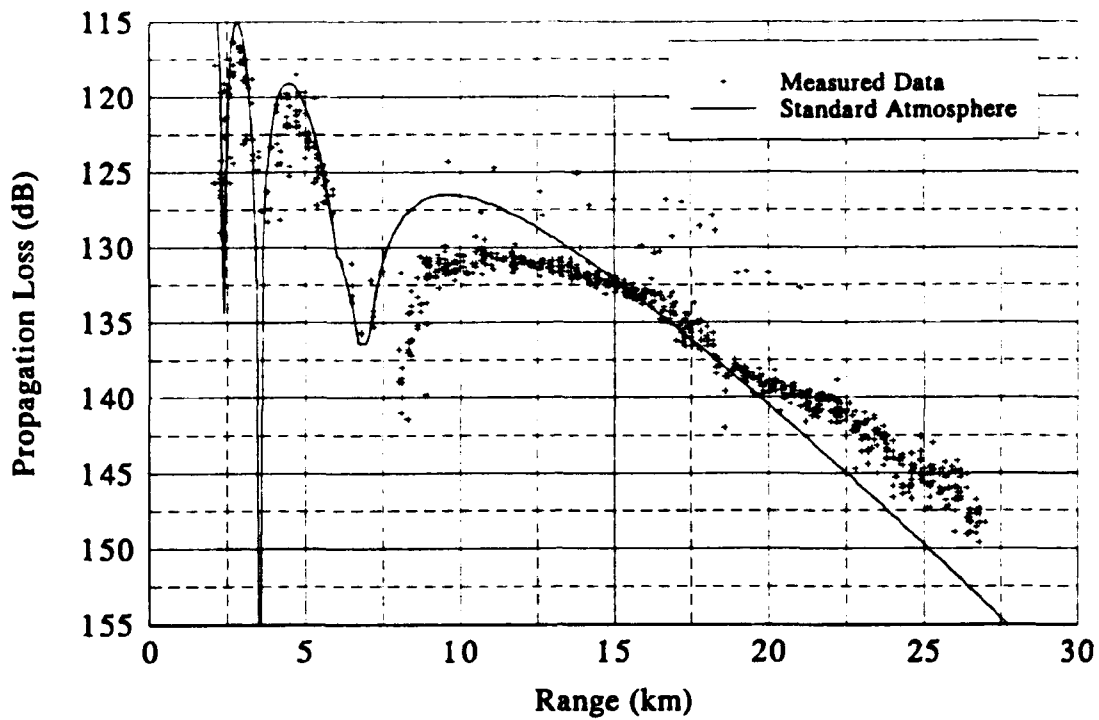


Figure 15. Propagation loss versus range measured on 01/30/91 from 09:46 to 10:20 PST; target height 4.9 m.

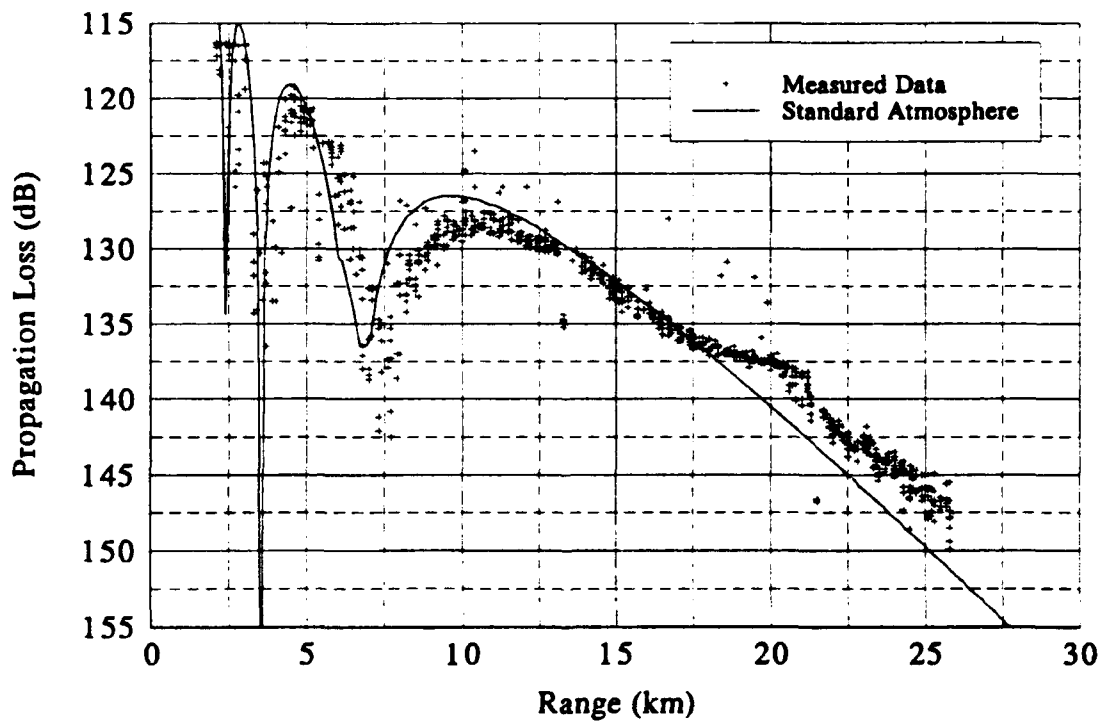


Figure 16. Propagation loss versus range measured on 01/30/91 from 11:01 to 11:33 PST; target height 4.9 m.

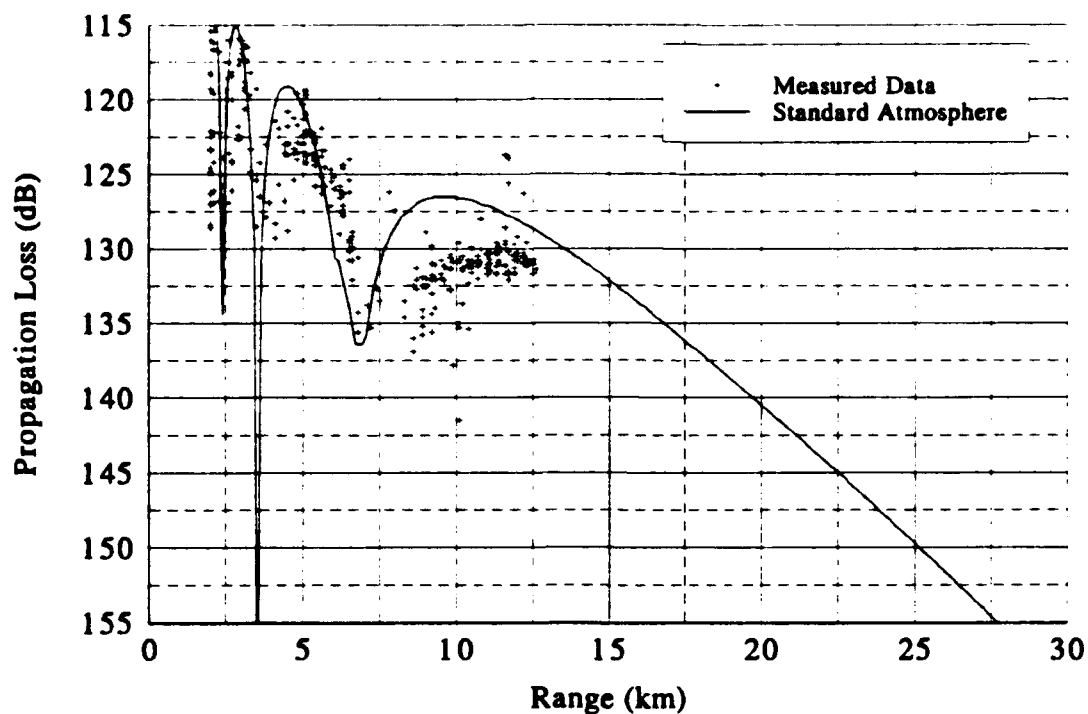


Figure 17. Propagation loss versus range measured on 01/30/91 from 11:39 to 11:56 PST; target height 4.9 m.

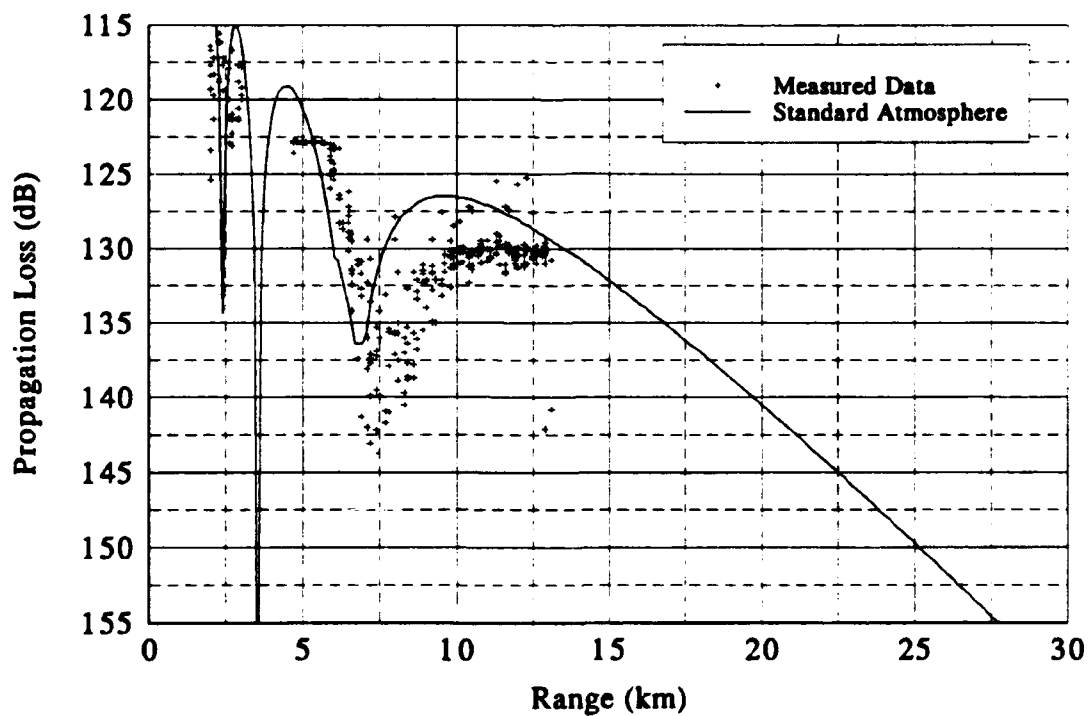


Figure 18. Propagation loss versus range measured on 01/30/91 from 12:01 to 12:16 PST; target height 4.9 m.

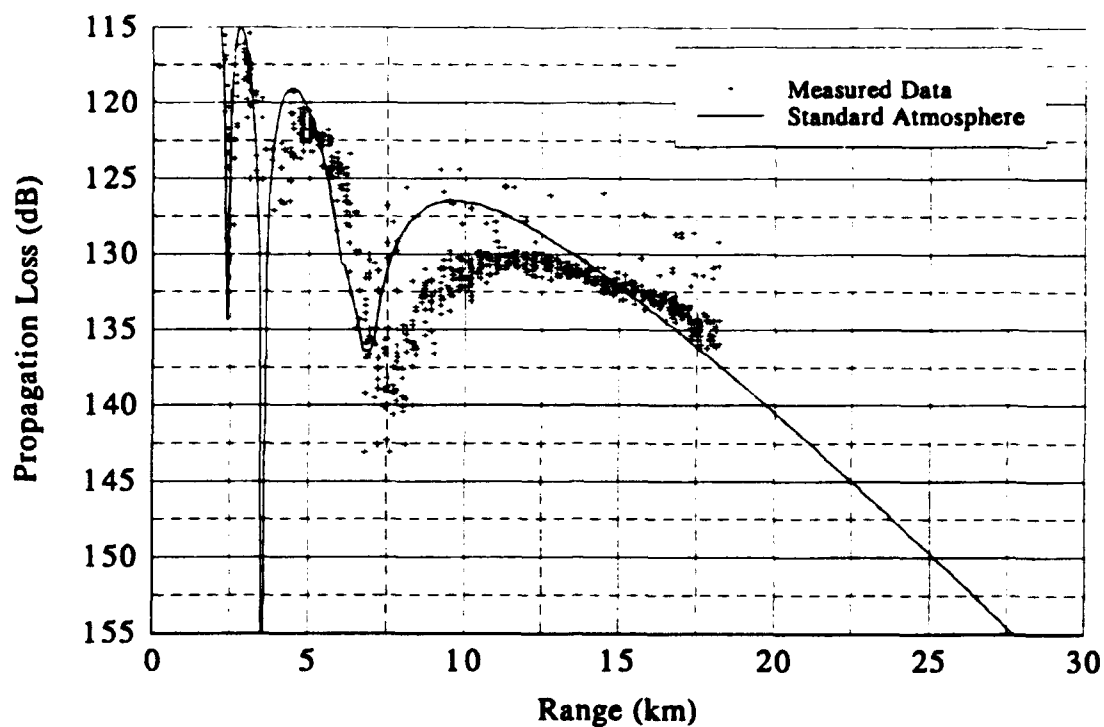


Figure 19. Propagation loss versus range measured on 01/30/91 from 12:23 to 12:54 PST; target height 4.9 m.

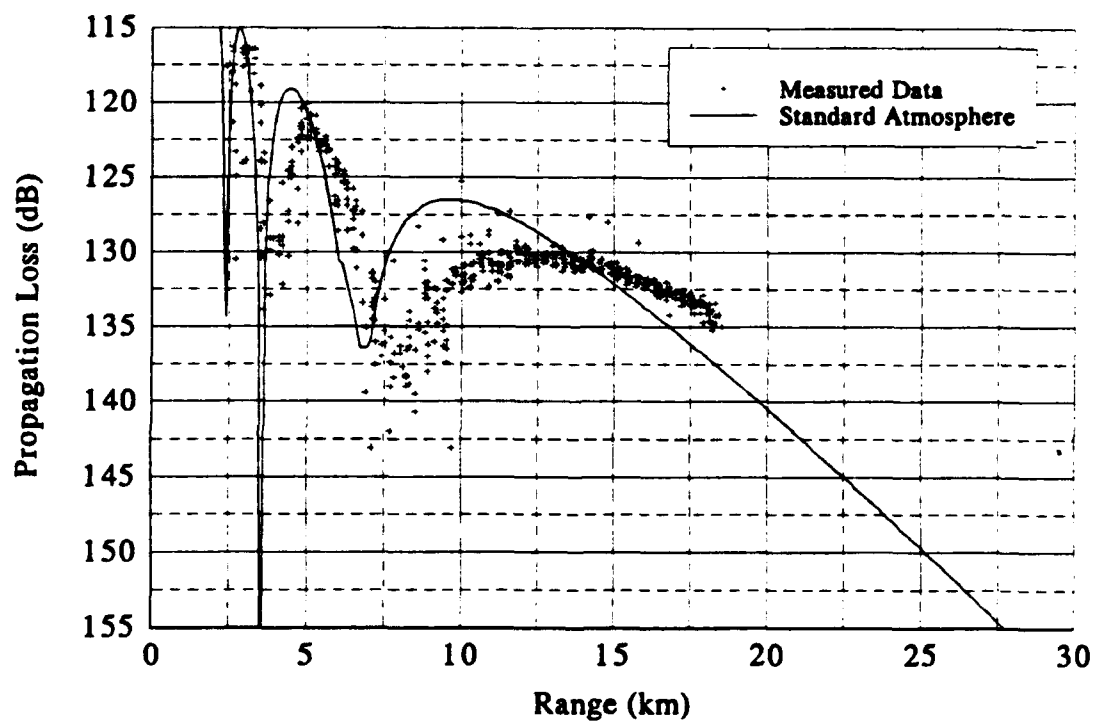


Figure 20. Propagation loss versus range measured on 01/30/91 from 13:01 to 13:21 PST; target height 4.9 m.

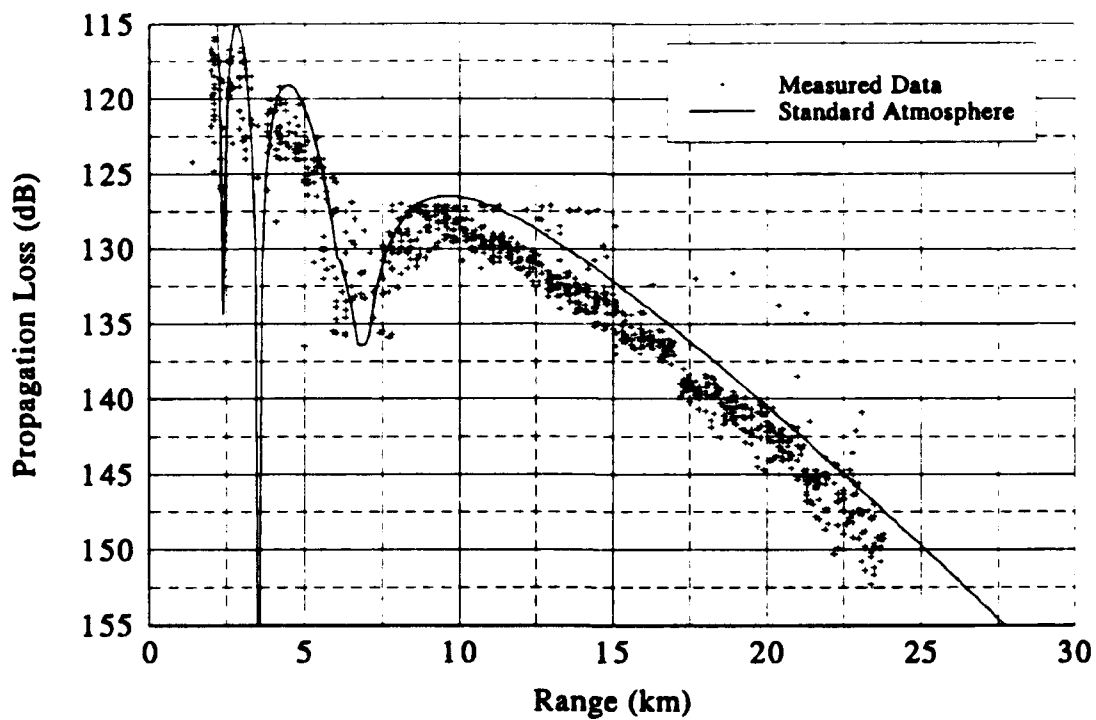


Figure 21. Propagation loss versus range measured on 02/13/91 from 10:06 to 10:42 PST; target height 4.9 m.

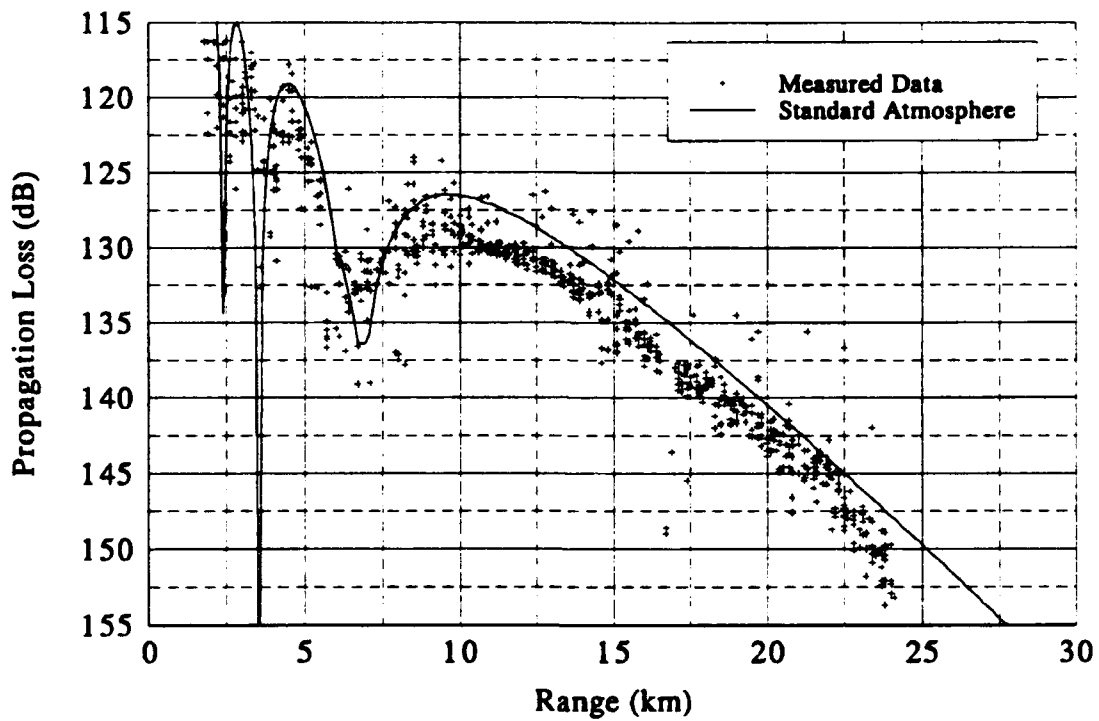


Figure 22. Propagation loss versus range measured on 02/13/91 from 10:49 to 11:19 PST; target height 4.9 m.

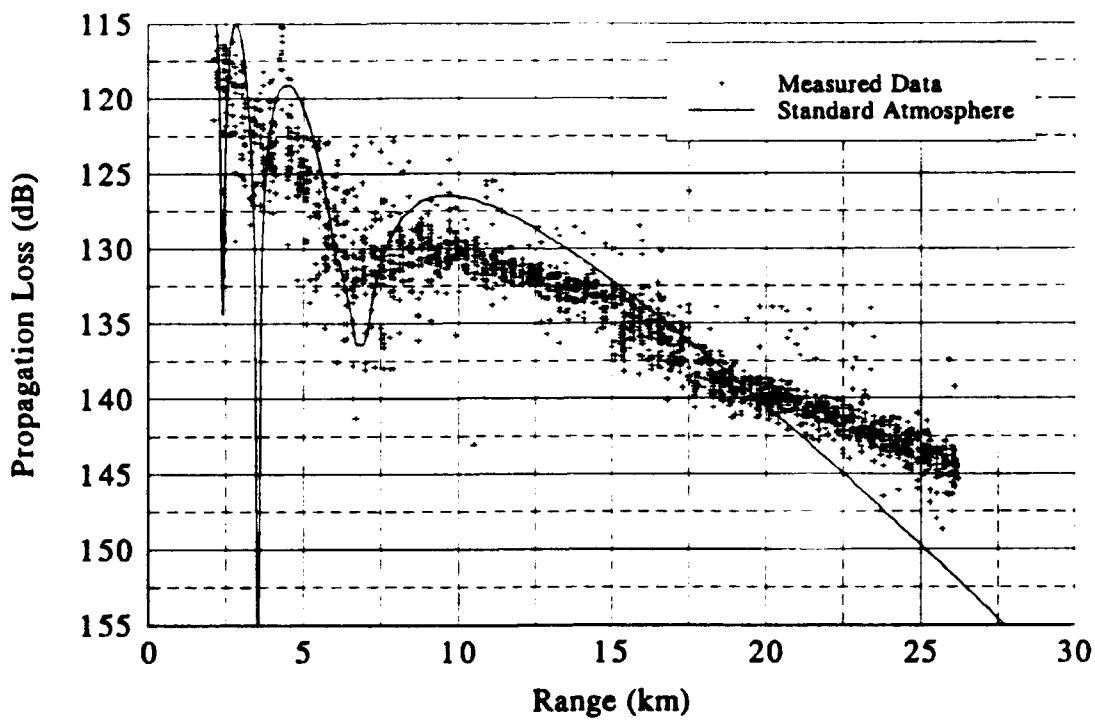


Figure 23. Propagation loss versus range measured on 03/06/91 from 10:17 to 11:36 PST; target height 4.9 m.

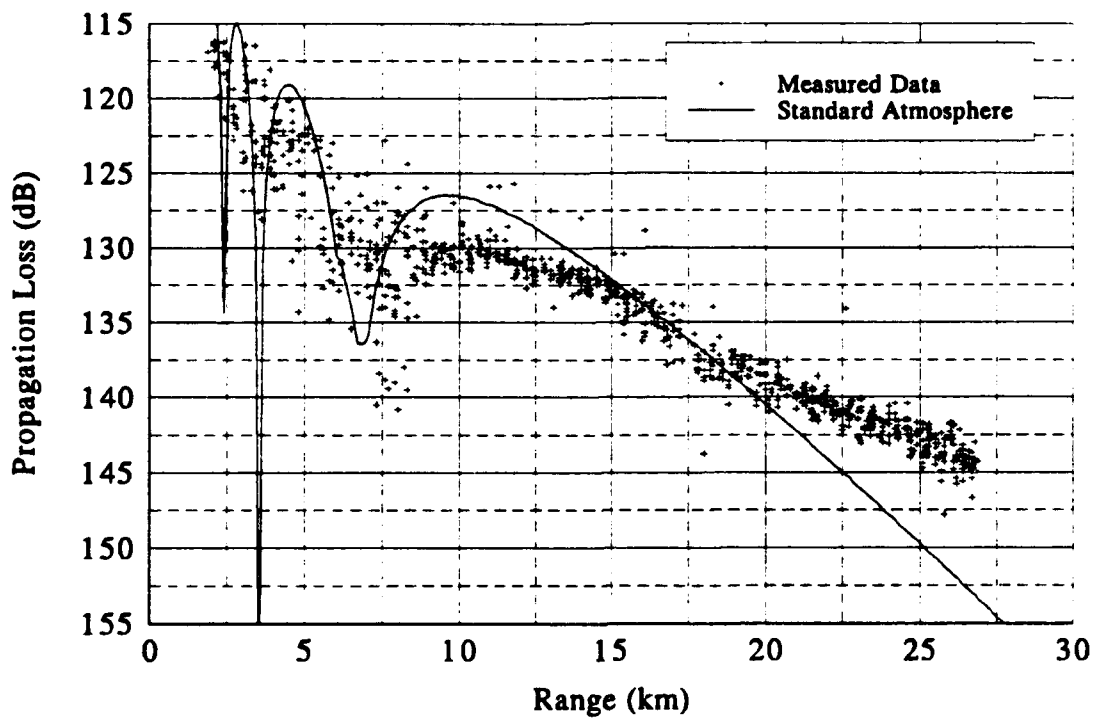


Figure 24. Propagation loss versus range measured on 03/06/91 from 11:44 to 12:21 PST; target height 4.9 m.

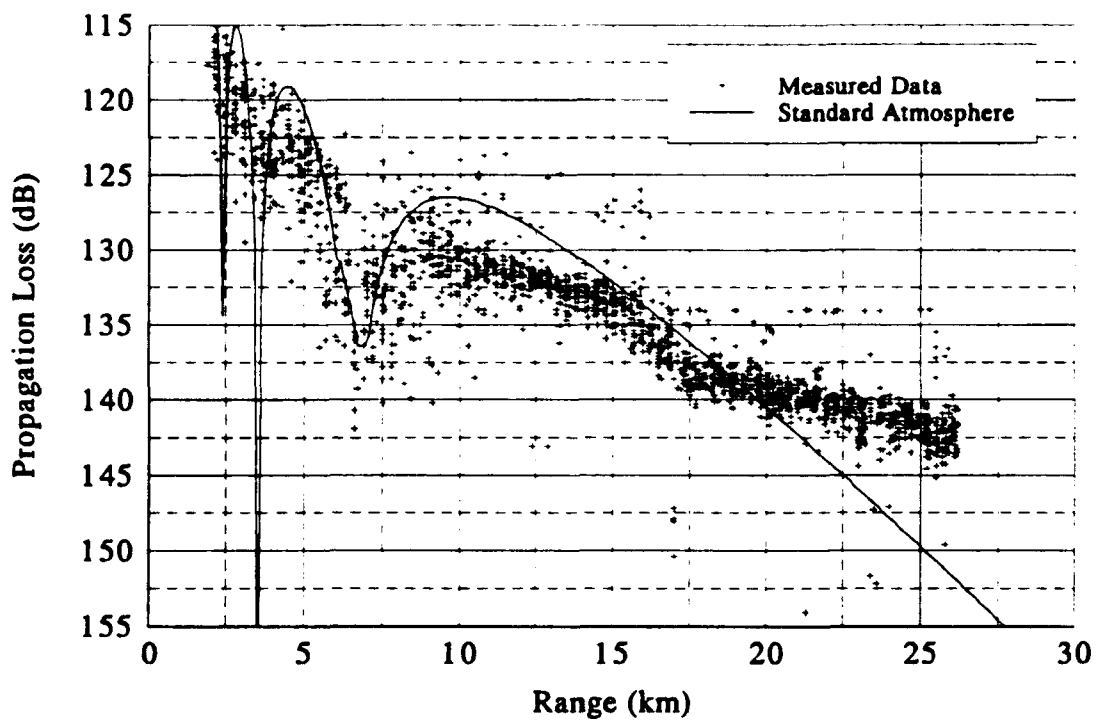


Figure 25. Propagation loss versus range measured on 03/11/91 from 13:12 to 14:30 PST; target height 4.9 m.

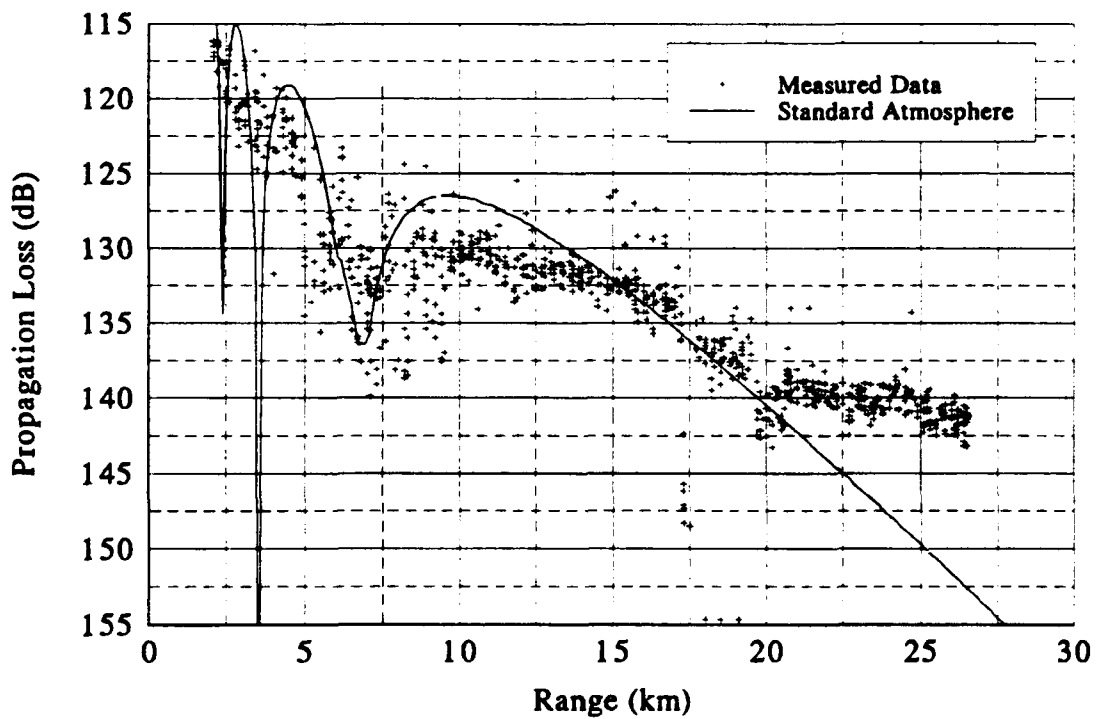


Figure 26. Propagation loss versus range measured on 03/11/91 from 14:37 to 15:11 PST; target height 4.9 m.

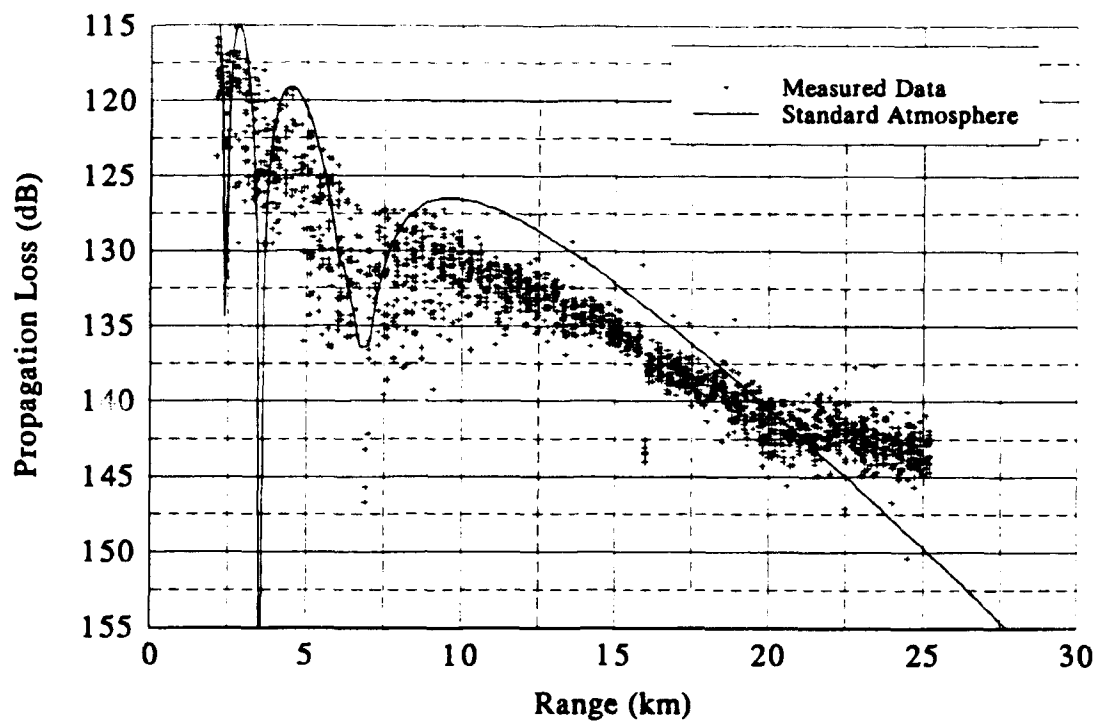


Figure 27. Propagation loss versus range measured on 03/14/91 from 10:15 to 11:33 PST; target height 4.9 m.

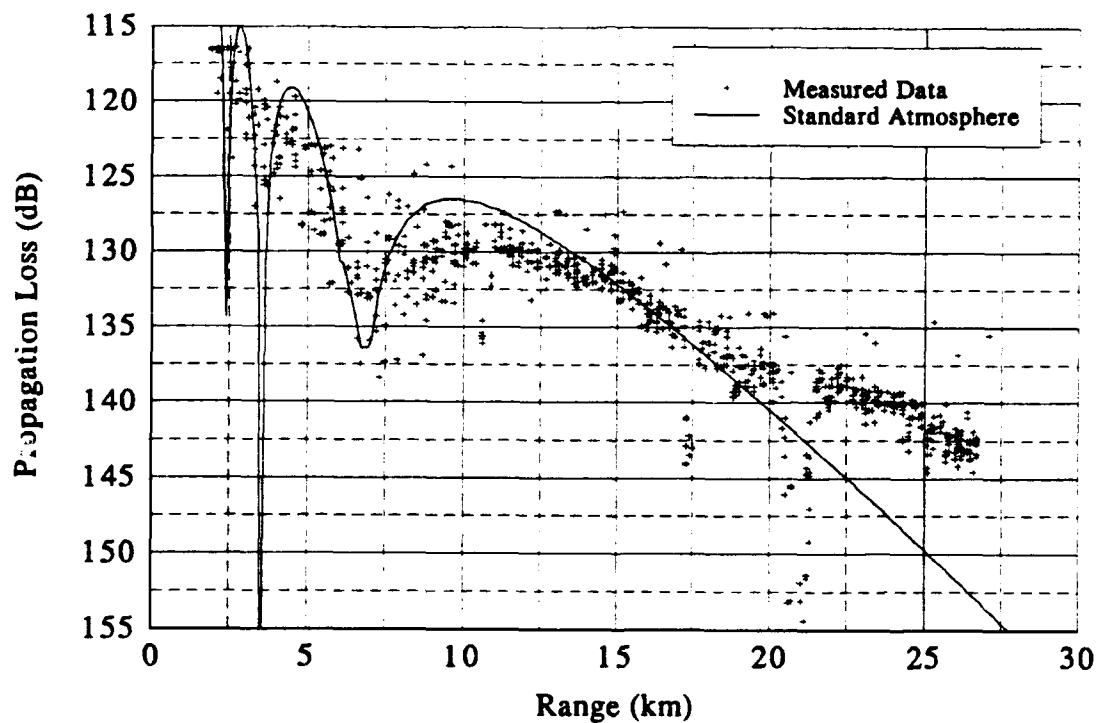


Figure 28. Propagation loss versus range measured on 03/14/91 from 12:04 to 12:35 PST; target height 4.9 m.

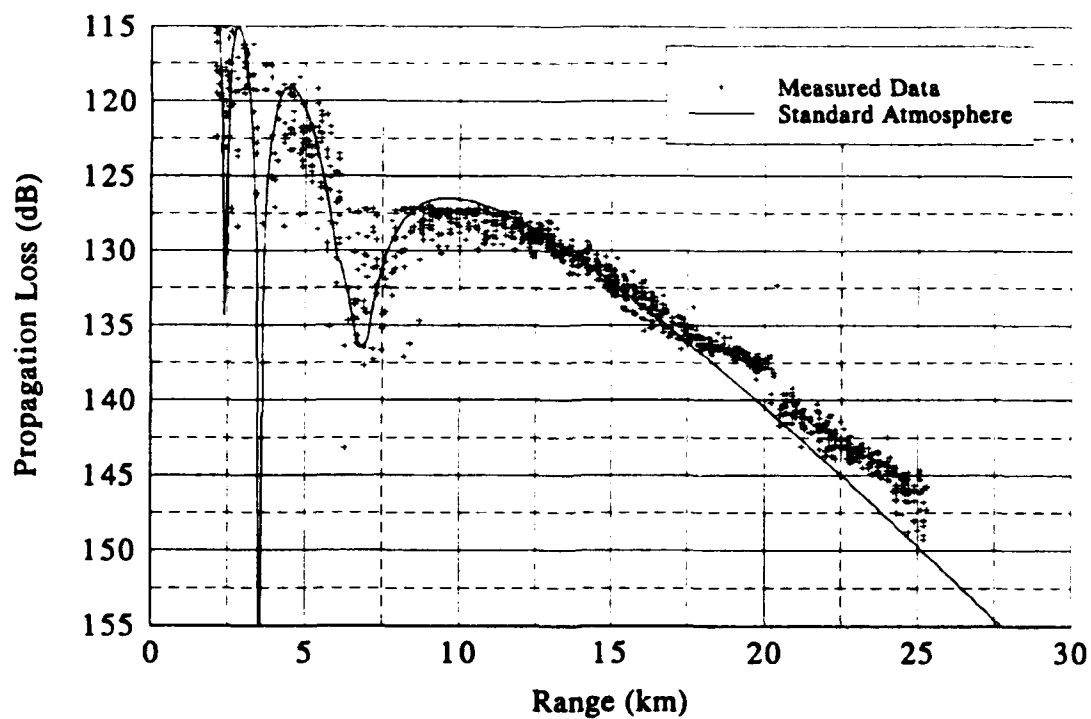


Figure 29. Propagation loss versus range measured on 04/30/91 from 10:00 to 10:42 PDT; target height 4.9 m.

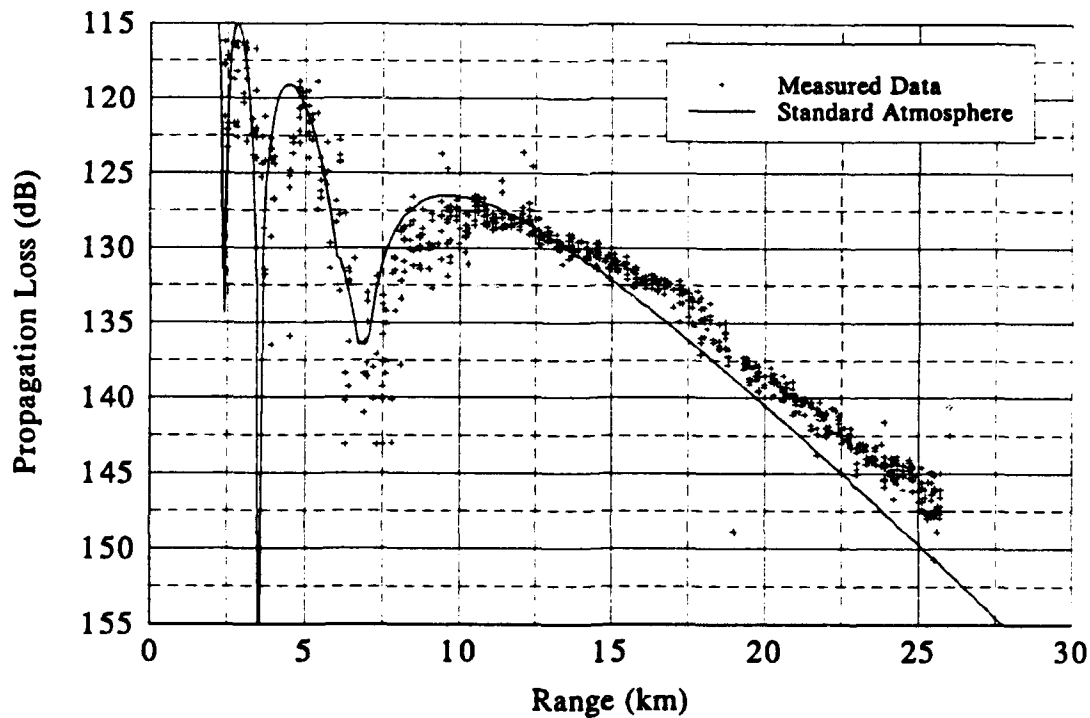


Figure 30. Propagation loss versus range measured on 04/30/91 from 10:48 to 11:16 PDT; target height 4.9 m.

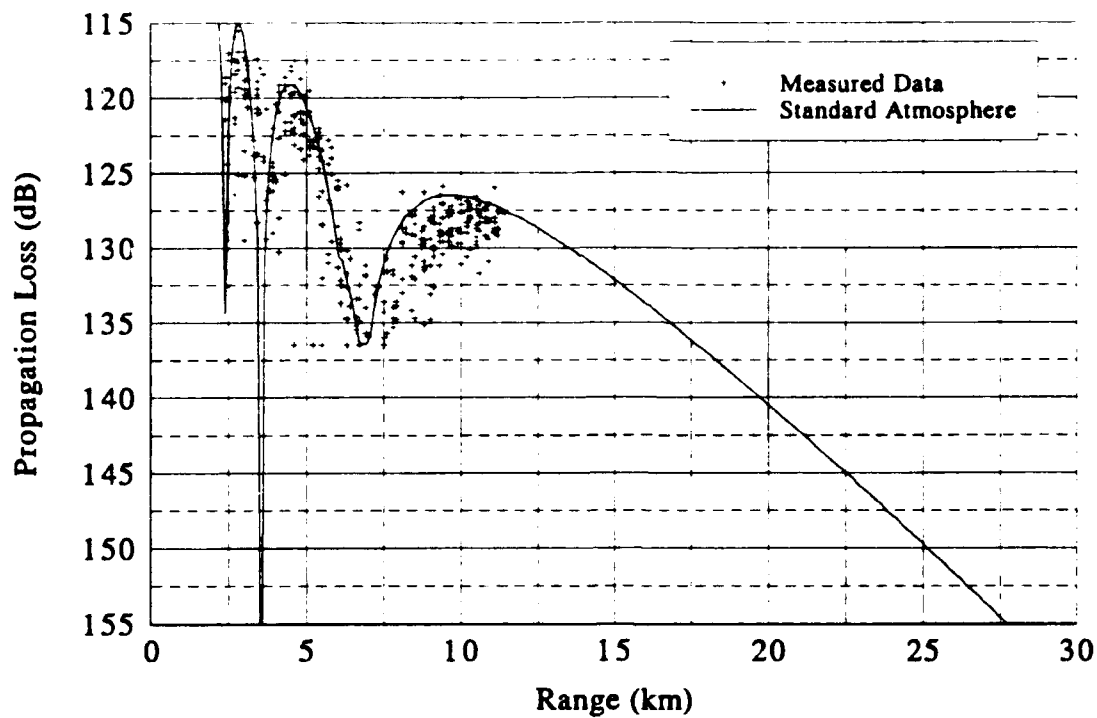


Figure 31. Propagation loss versus range measured on 04/30/91 from 11:26 to 11:41 PDT; target height 4.9 m.

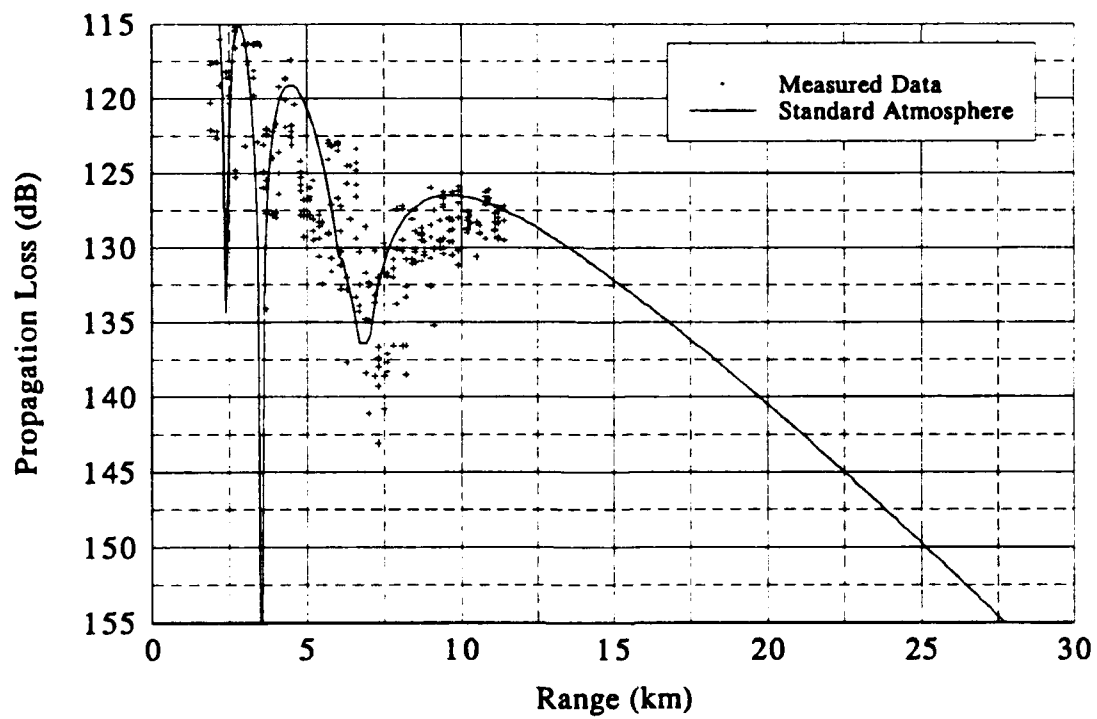


Figure 32. Propagation loss versus range measured on 04/30/91 from 11:47 to 11:58 PDT; target height 4.9 m.

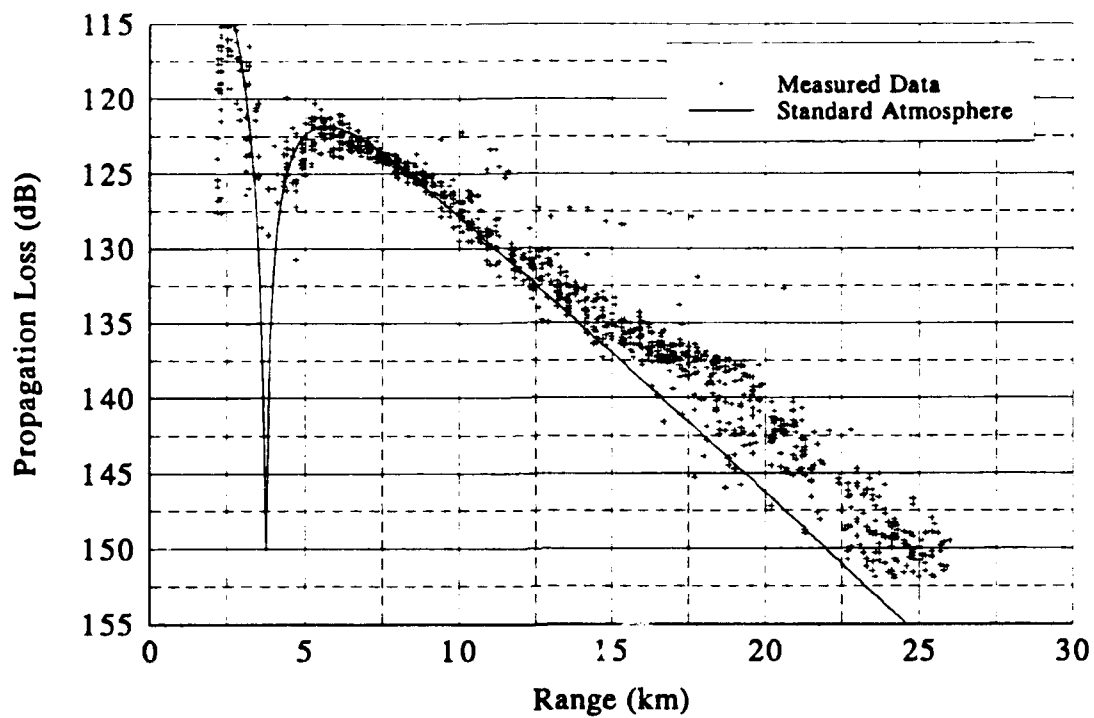


Figure 33. Propagation loss versus range measured on 08/01/91 from 13:13 to 14:01 PDT; target height 4.9 m.

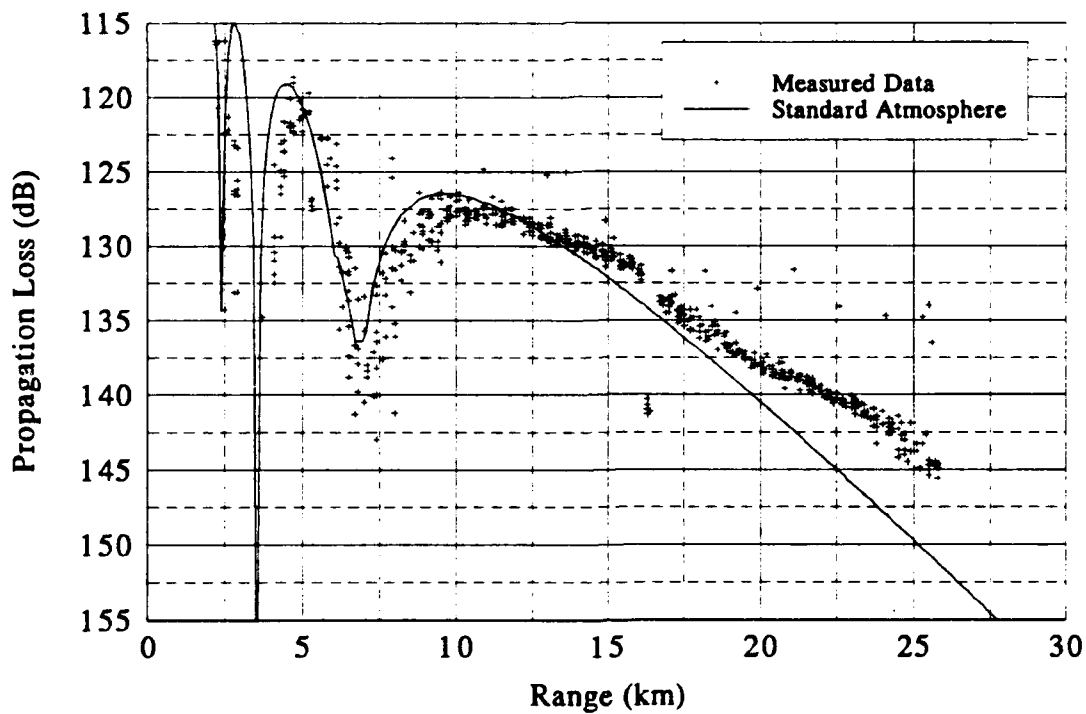


Figure 34. Propagation loss versus range measured on 08/01/91 from 14:08 to 14:36 PDT; target height 4.9 m.

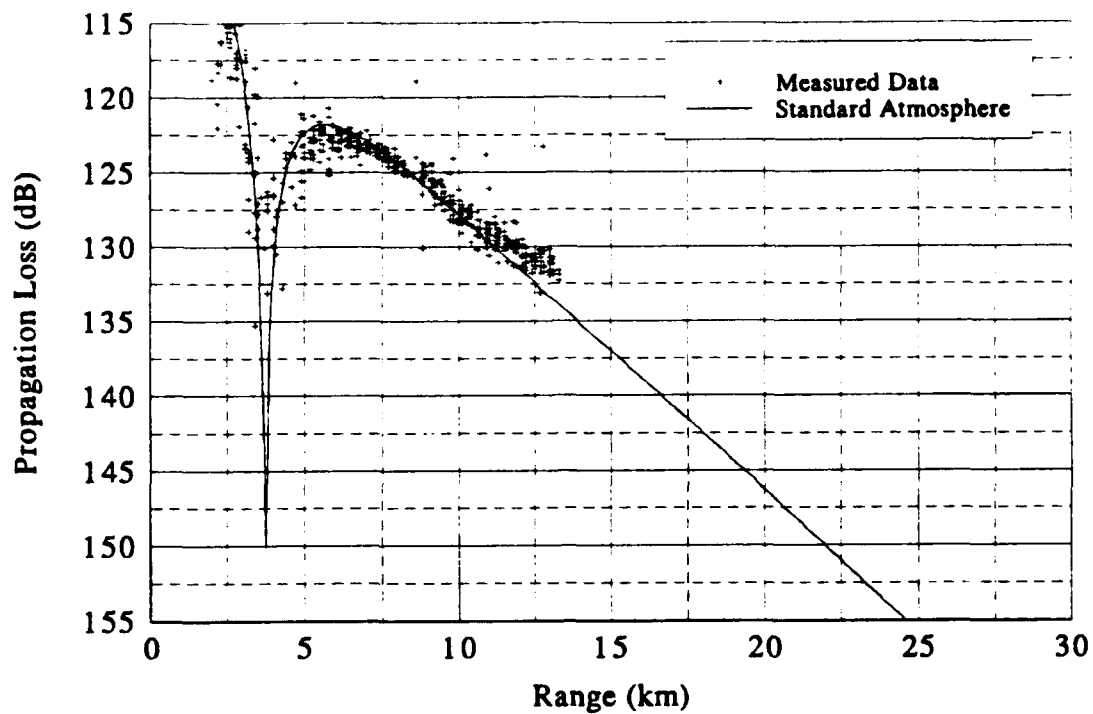


Figure 35. Propagation loss versus range measured on 08/01/91 from 14:44 to 15:04 PDT; target height 4.9 m.

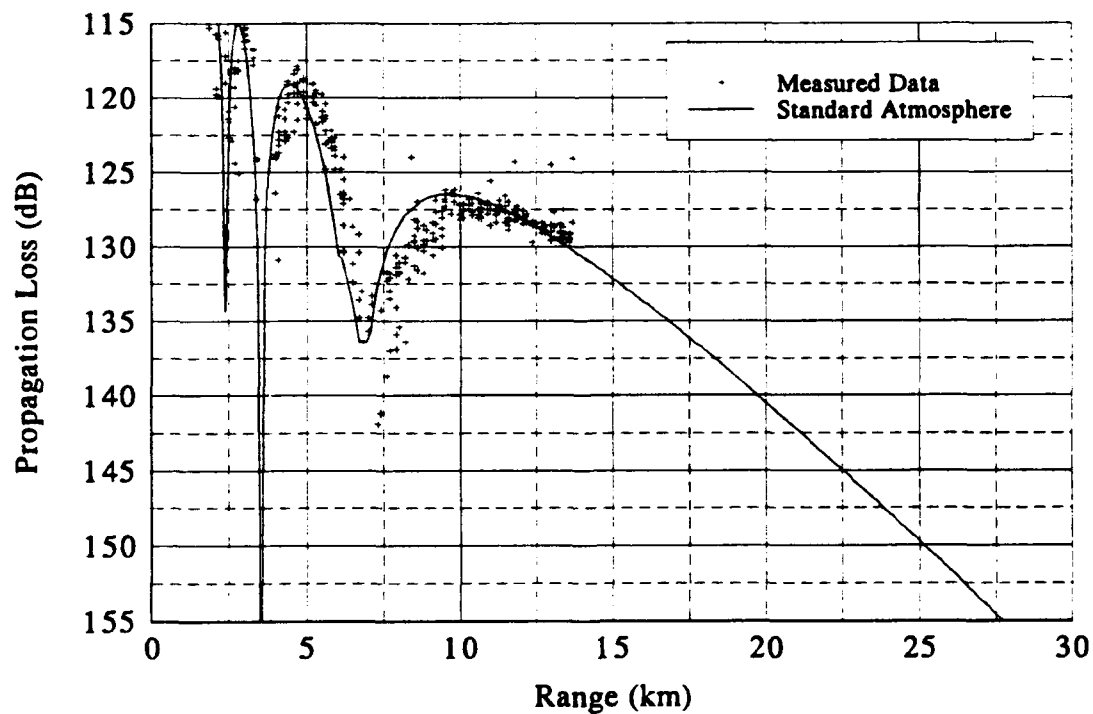


Figure 36. Propagation loss versus range measured on 08/01/91 from 15:12 to 15:27 PDT; target height 4.9 m.

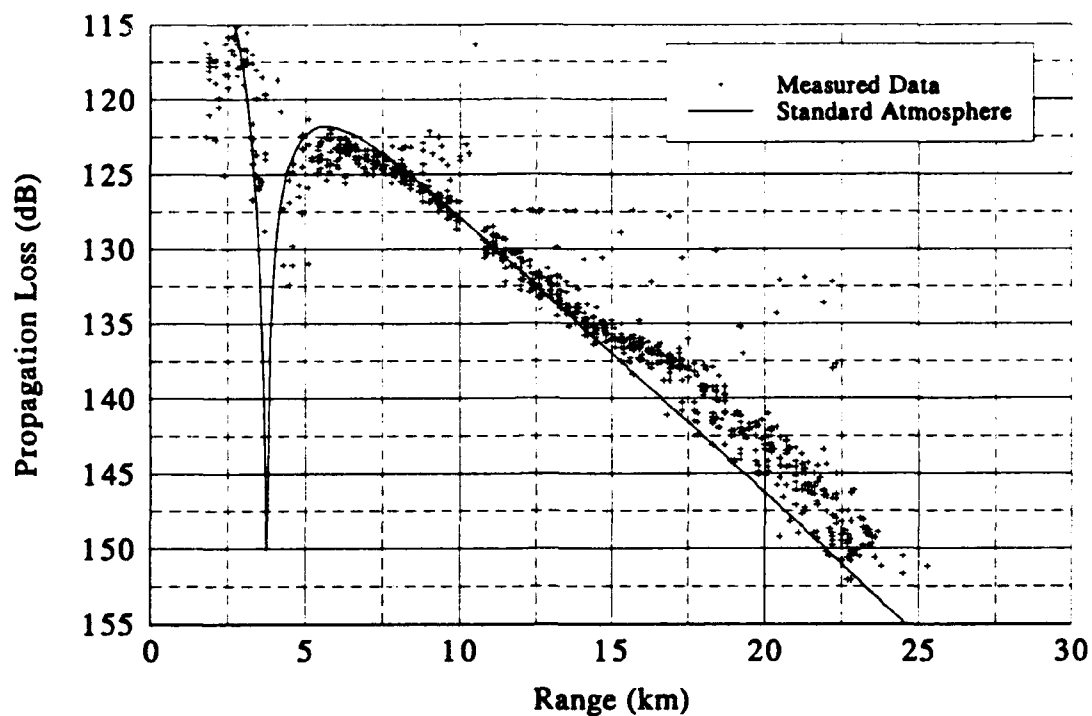


Figure 37. Propagation loss versus range measured on 08/08/91 from 12:02 to 12:39 PDT; target height 4.9 m.

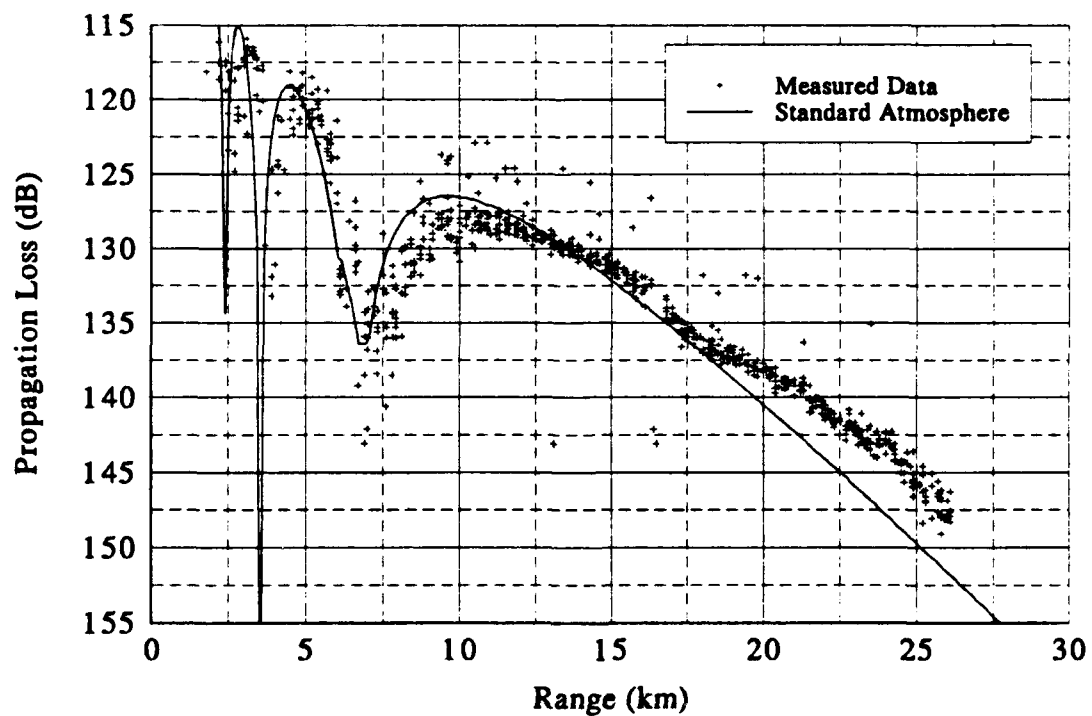


Figure 38. Propagation loss versus range measured on 08/08/91 from 12:48 to 13:17 PDT; target height 4.9 m.

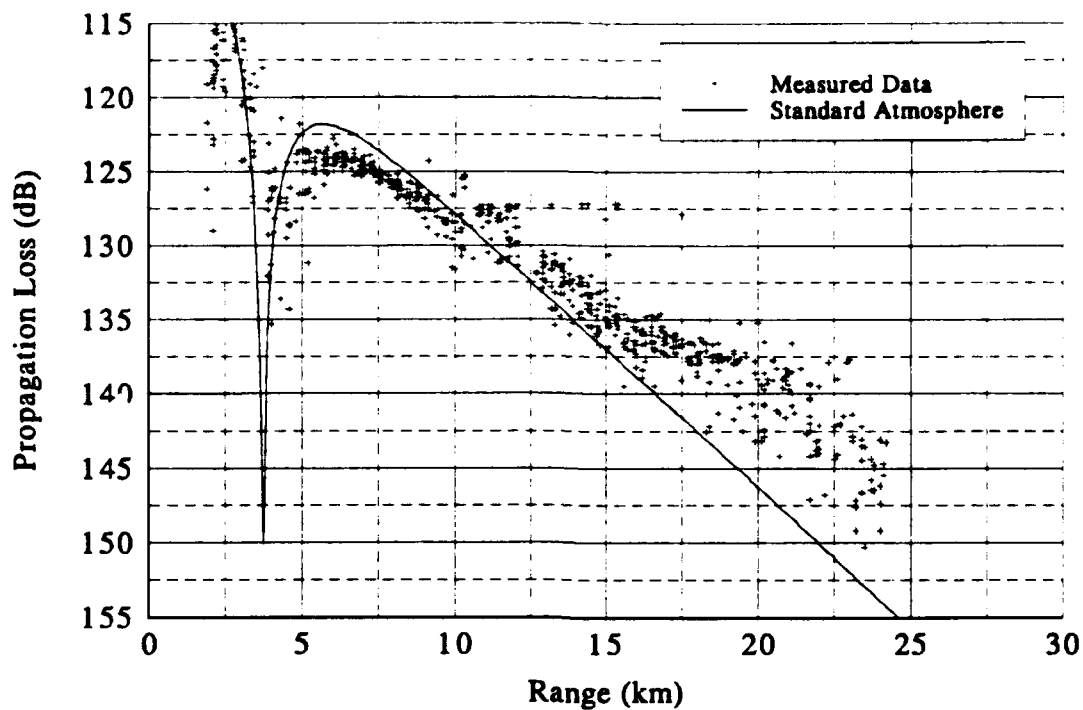


Figure 39. Propagation loss versus range measured on 08/15/91 from 12:06 to 12:46 PDT; target height 4.9 m.

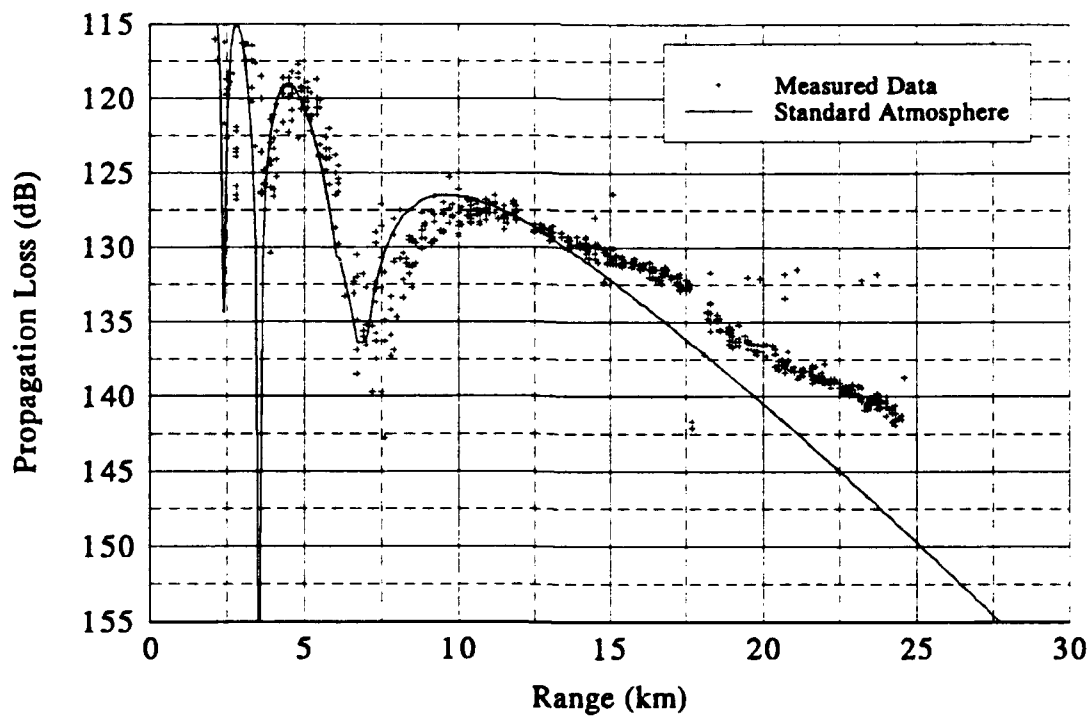


Figure 40. Propagation loss versus range measured on 08/15/91 from 12:54 to 13:27 PDT; target height 4.9 m.

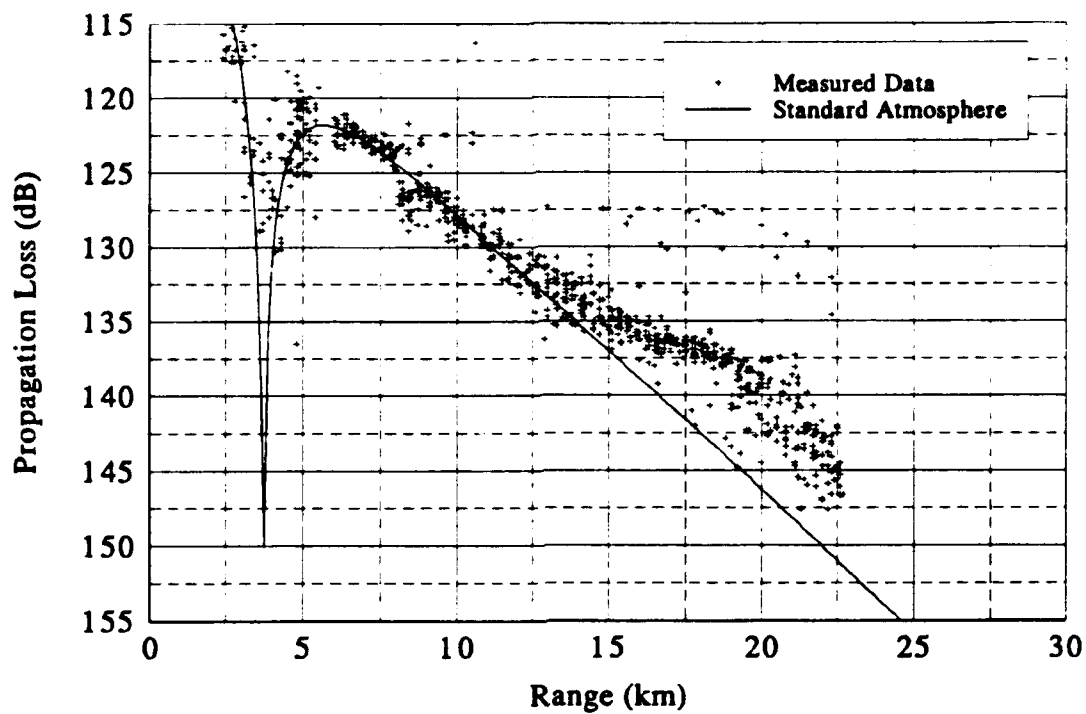


Figure 41. Propagation loss versus range measured on 09/12/91 from 11:44 to 12:21 PDT; target height 4.9 m.

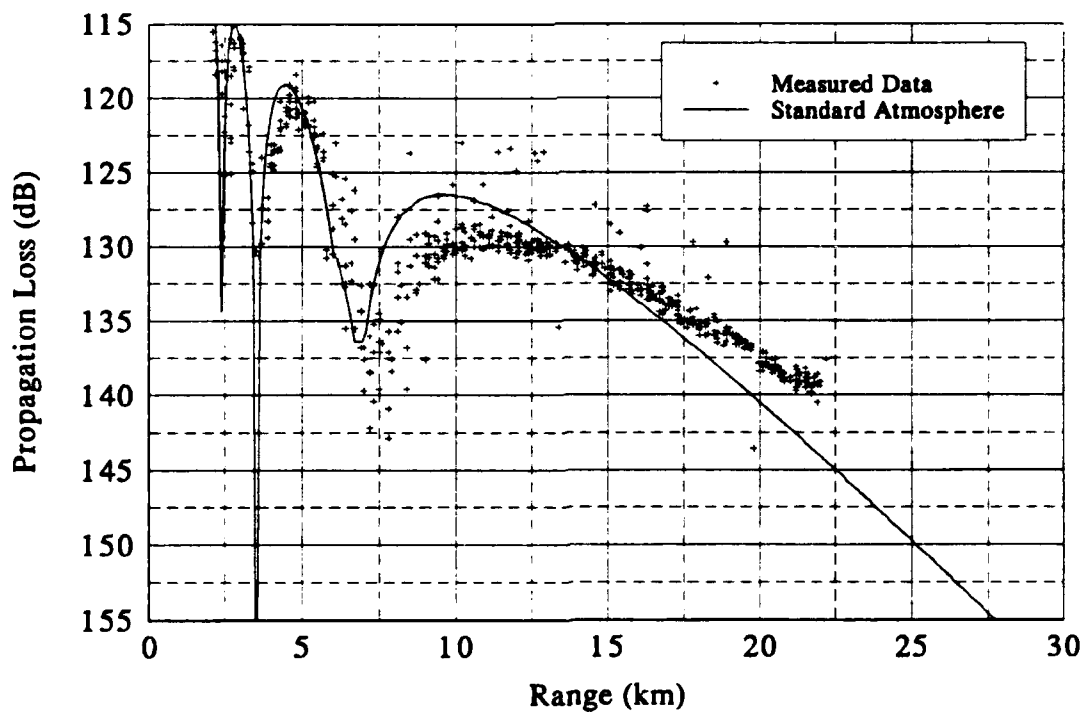


Figure 42. Propagation loss versus range measured on 09/12/91 from 12:30 to 12:54 PDT; target height 4.9 m.

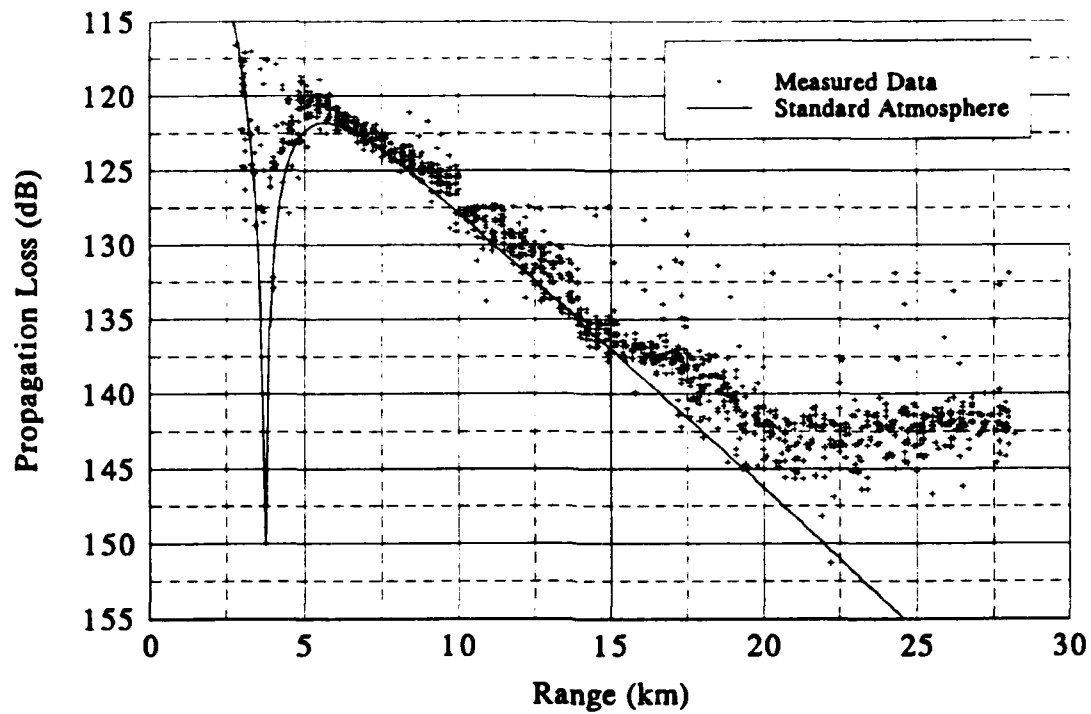


Figure 43. Propagation loss versus range measured on 10/10/91 from 12:04 to 13:01 PDT; target height 4.9 m.

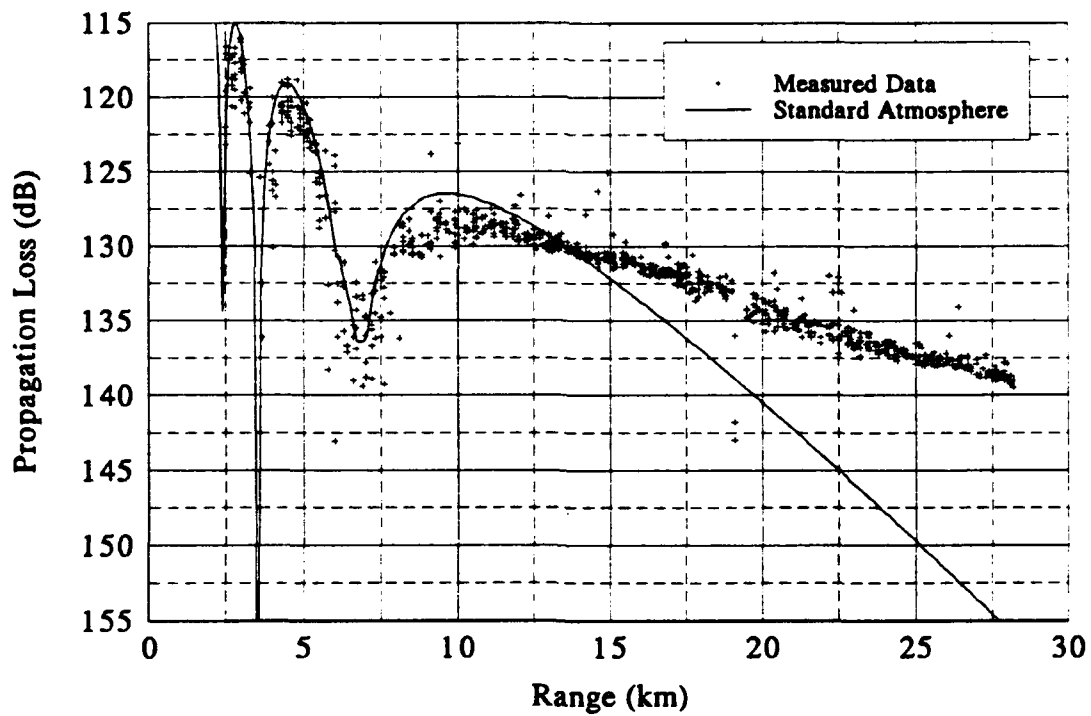


Figure 44. Propagation loss versus range measured on 10/10/91 from 13:09 to 13:44 PDT; target height 4.9 m.

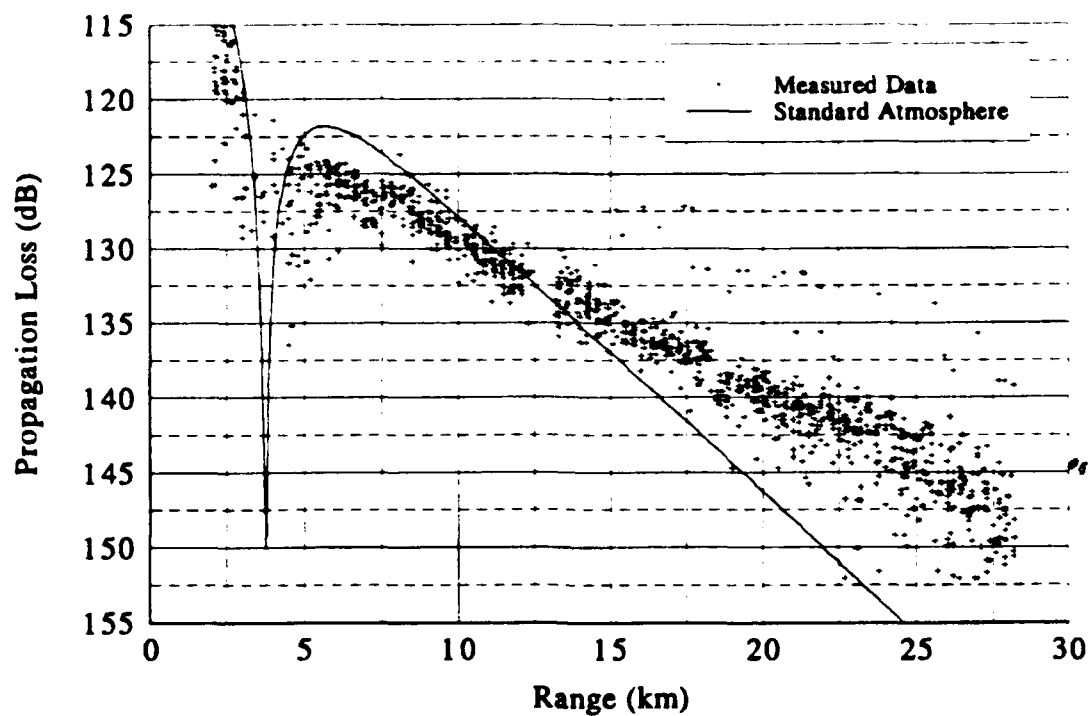


Figure 45. Propagation loss versus range measured on 10/24/91 from 13:05 to 14:11 PDT; target height 4.9 m.

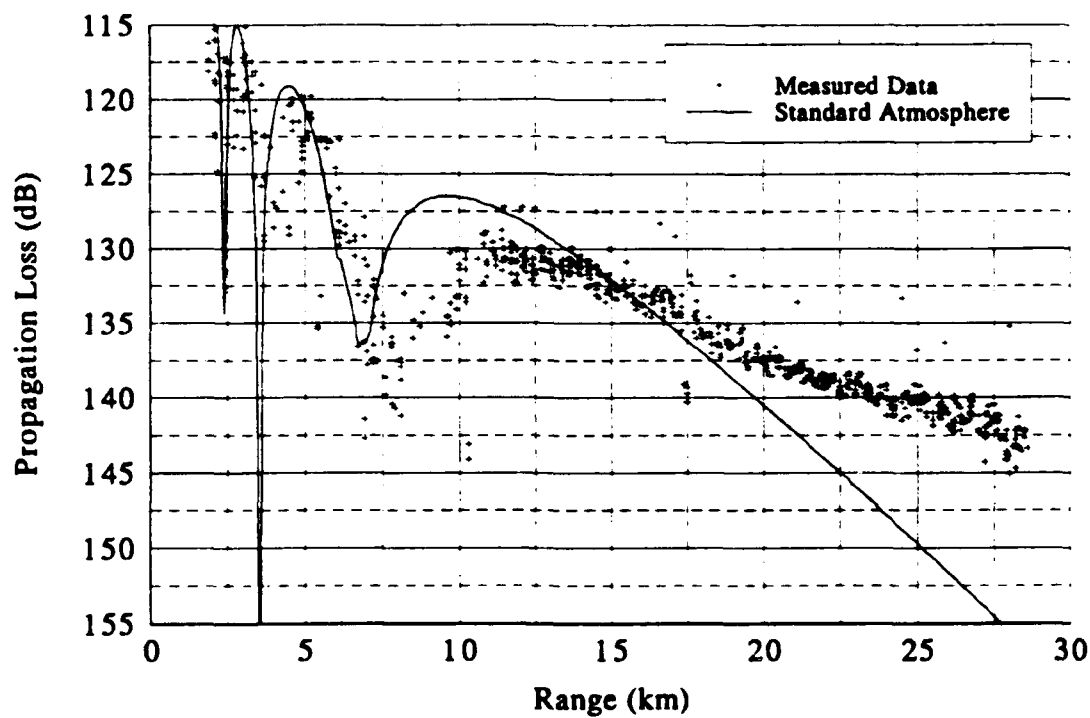


Figure 46. Propagation loss versus range measured on 10/24/91 from 14:17 to 14:49 PDT; target height 4.9 m.

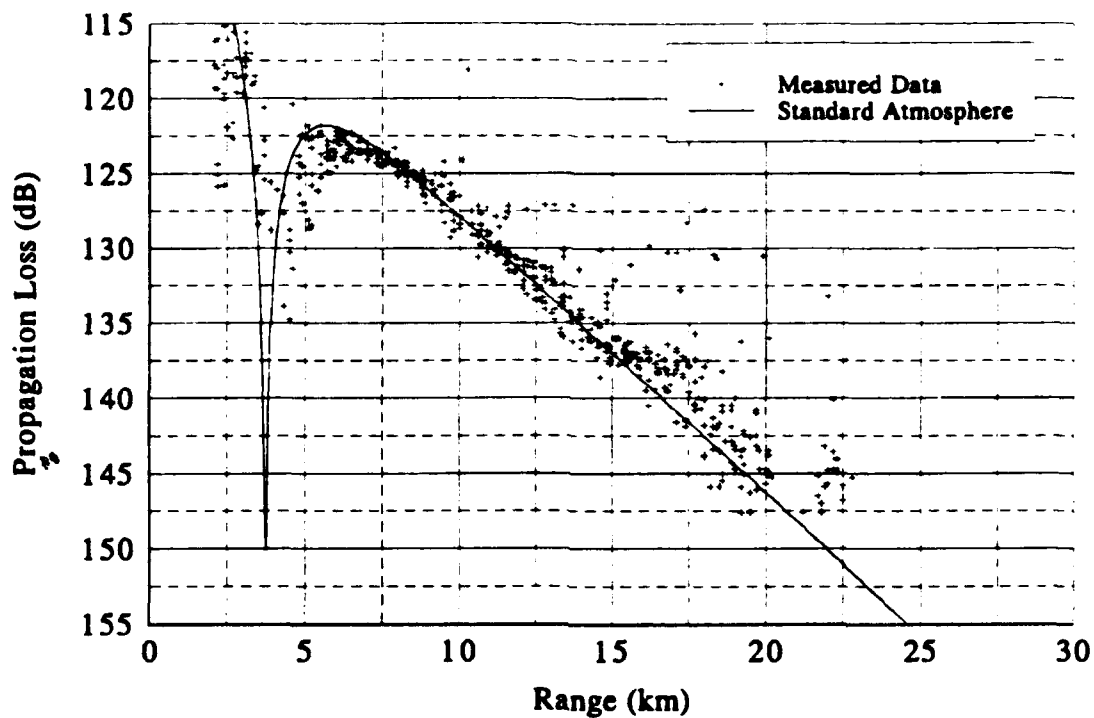


Figure 47. Propagation loss versus range measured on 12/05/91 from 12:06 to 12:48 PST; target height 4.9 m.

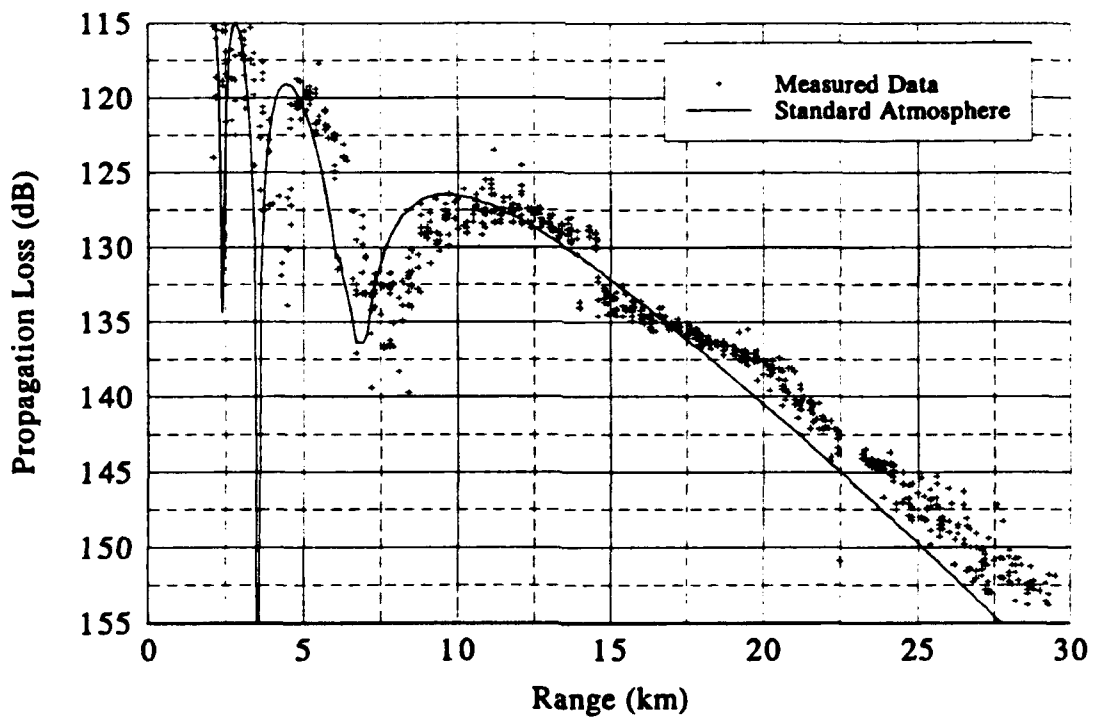


Figure 48. Propagation loss versus range measured on 12/05/91 from 13:54 to 14:27 PST; target height 4.9 m.

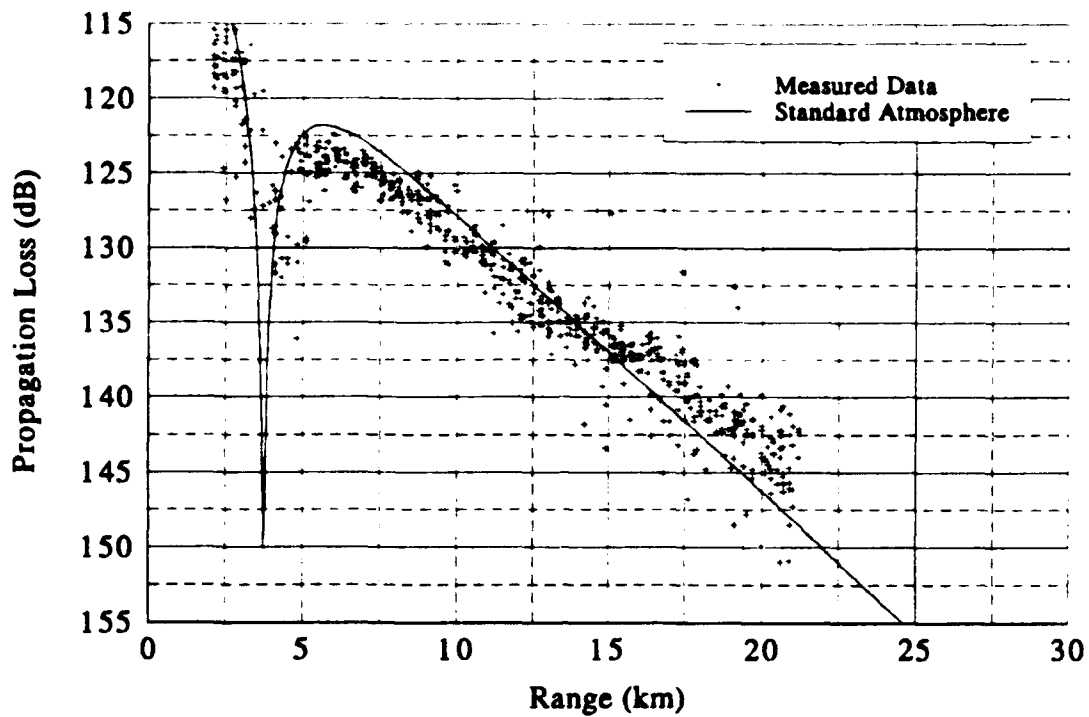


Figure 49. Propagation loss versus range measured on 12/12/91 from 10:37 to 11:05 PST; target height 4.9 m.

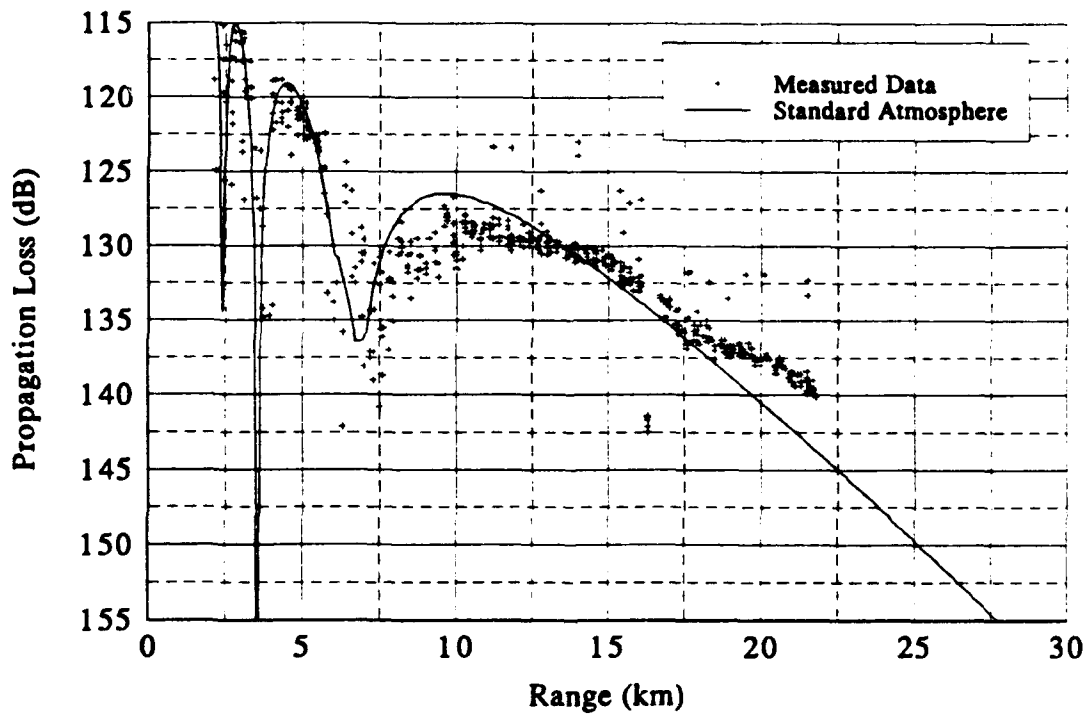


Figure 50. Propagation loss versus range measured on 12/12/91 from 11:20 to 11:42 PST; target height 4.9 m.

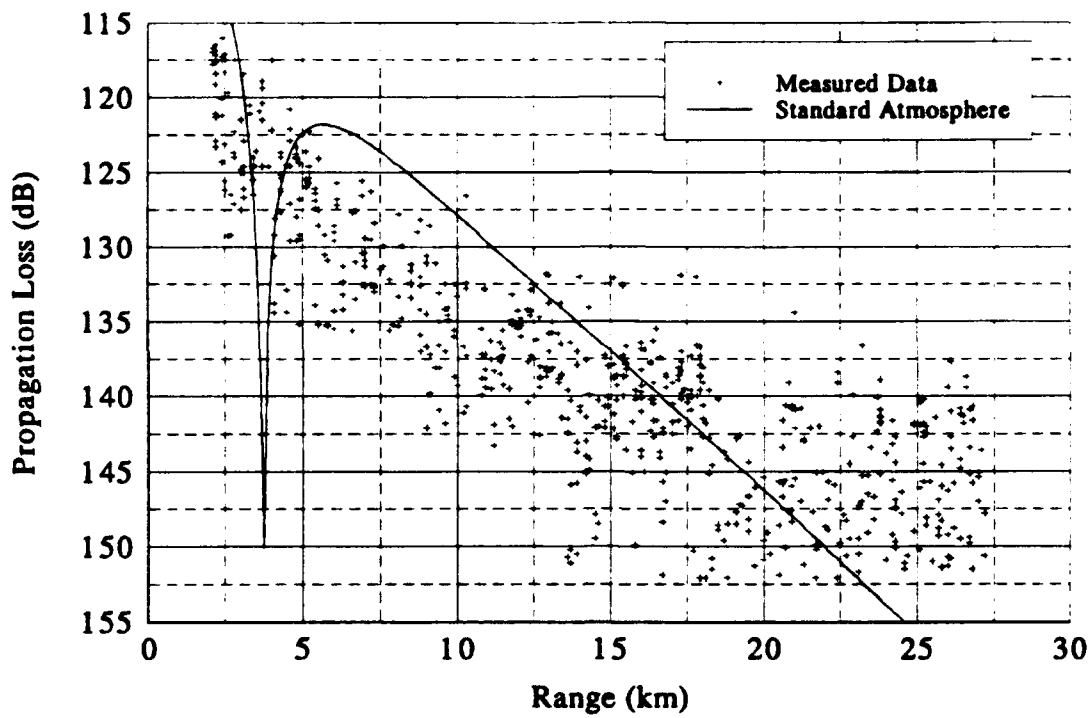


Figure 51. Propagation loss versus range measured on 01/31/92 from 10:32 to 11:05 PST; target height 4.9 m.

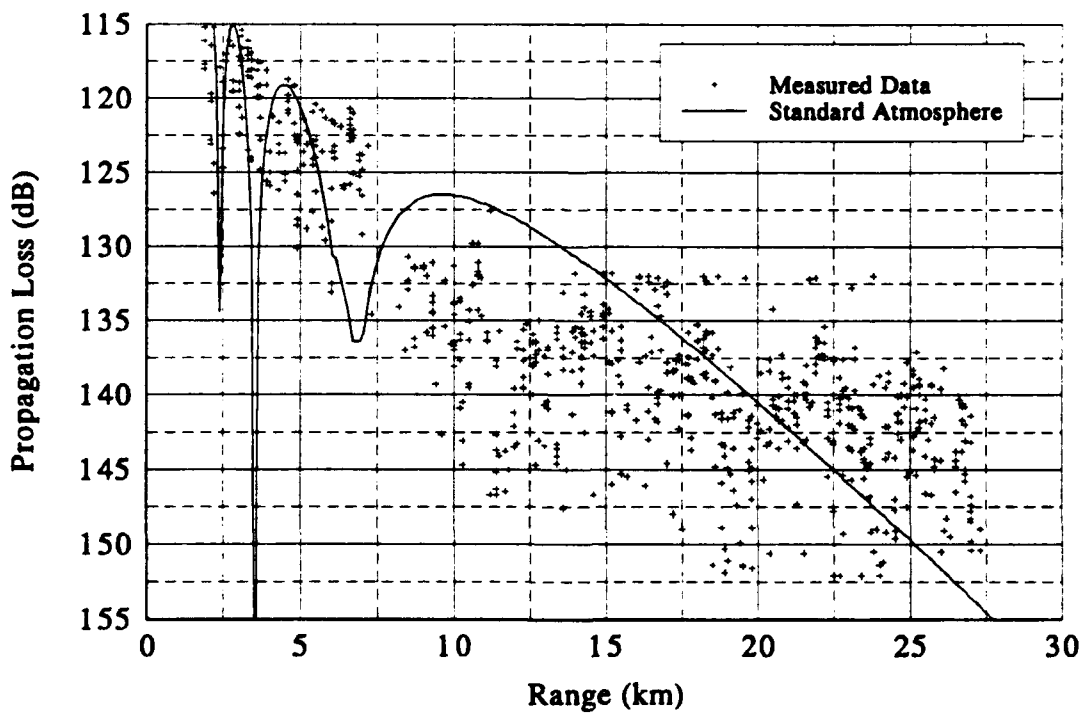


Figure 52. Propagation loss versus range measured on 01/31/92 from 11:12 to 11:58 PST; target height 4.9 m.

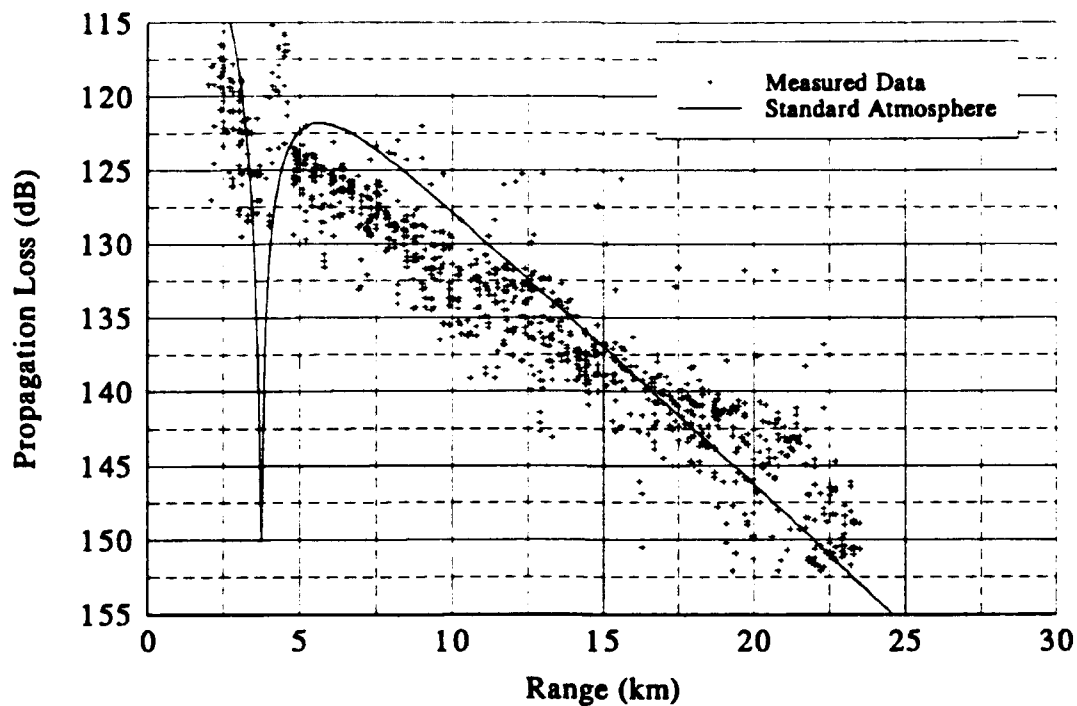


Figure 53. Propagation loss versus range measured on 02/14/92 from 10:04 to 10:46 PST; target height 4.9 m.

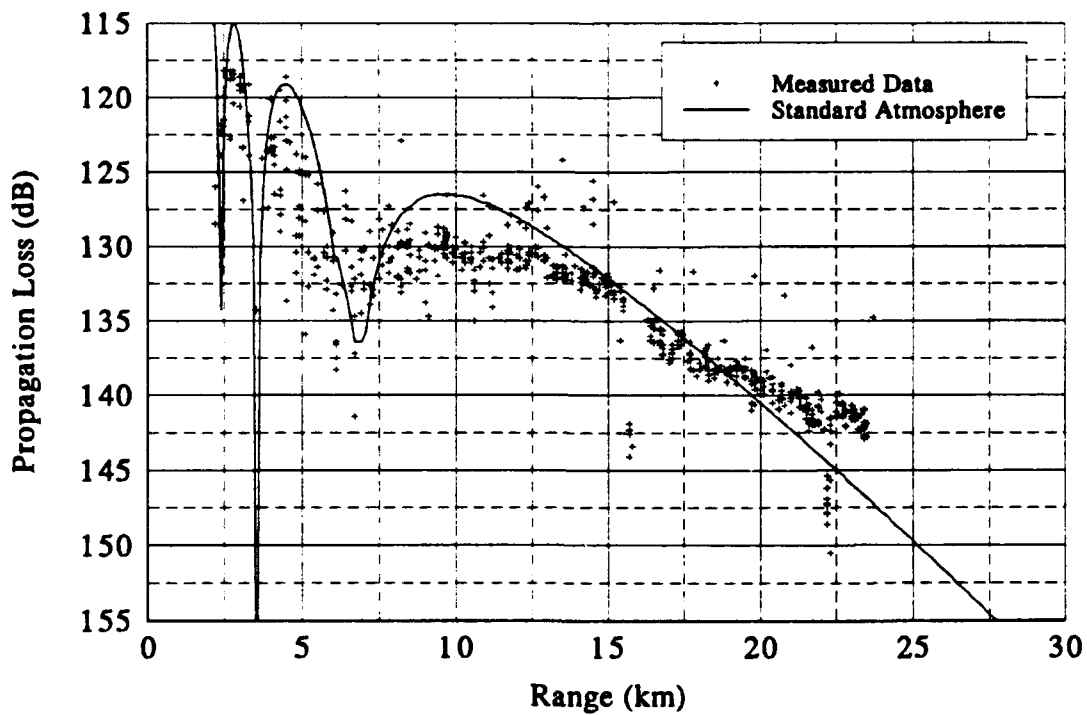


Figure 54. Propagation loss versus range measured on 02/14/92 from 11:07 to 11:34 PST; target height 4.9 m.

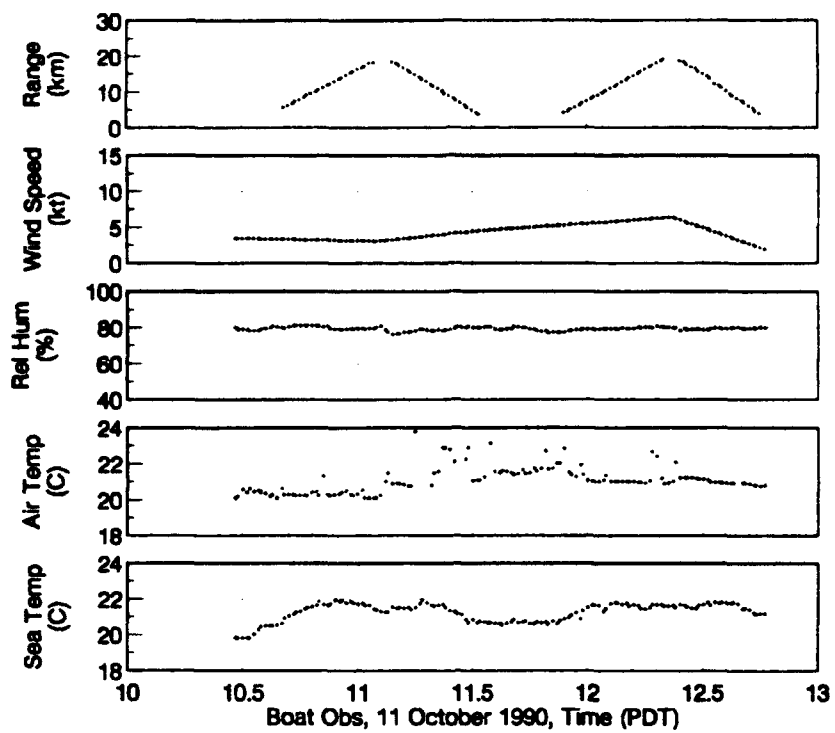


Figure 55. Surface meteorological observations as measured on the boat for 10/11/90.

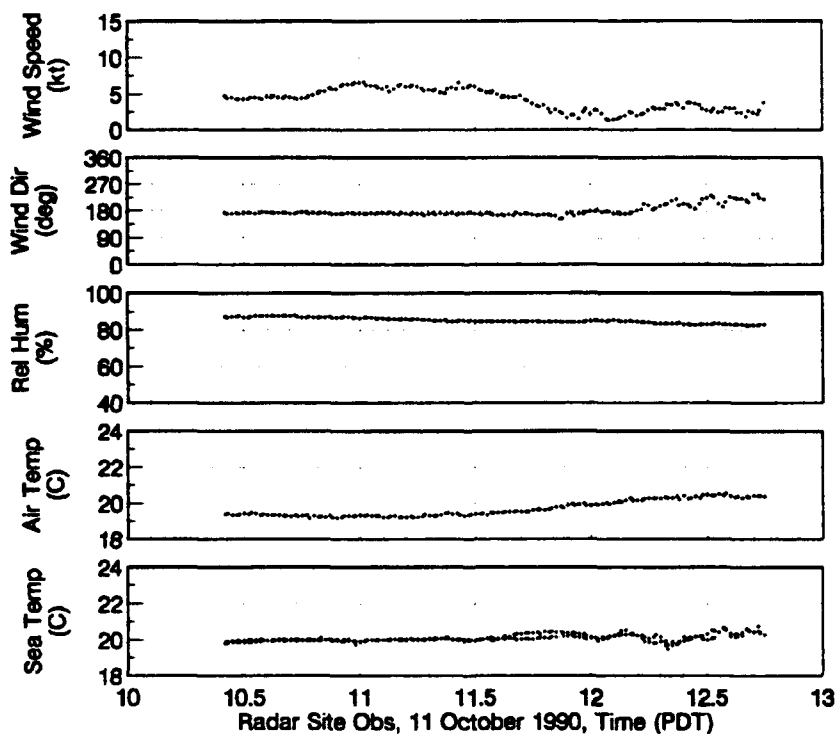


Figure 56. Surface meteorological observations as measured at the F35 site for 10/11/90.

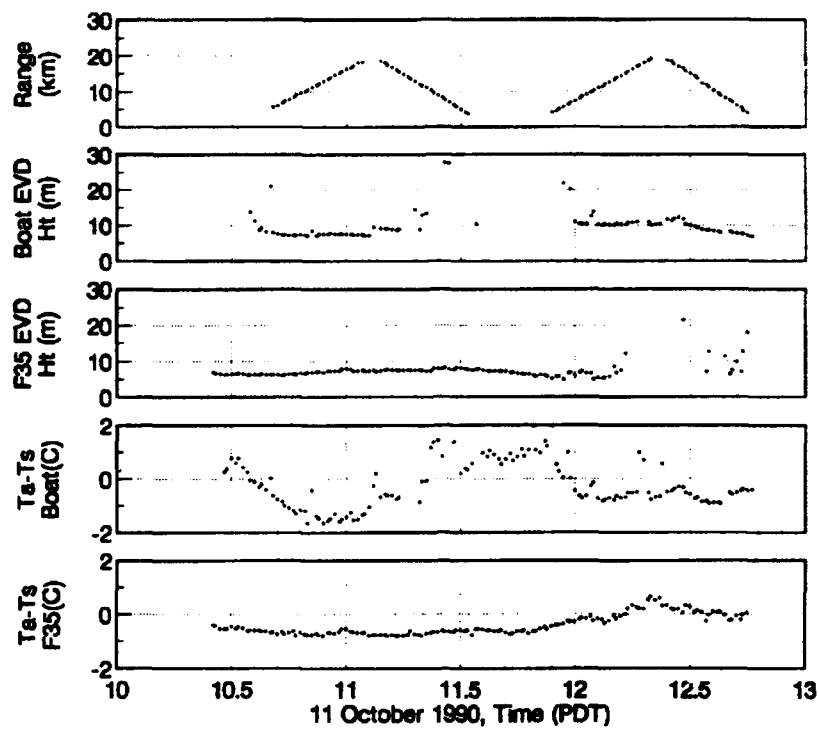


Figure 57. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 10/11/90.

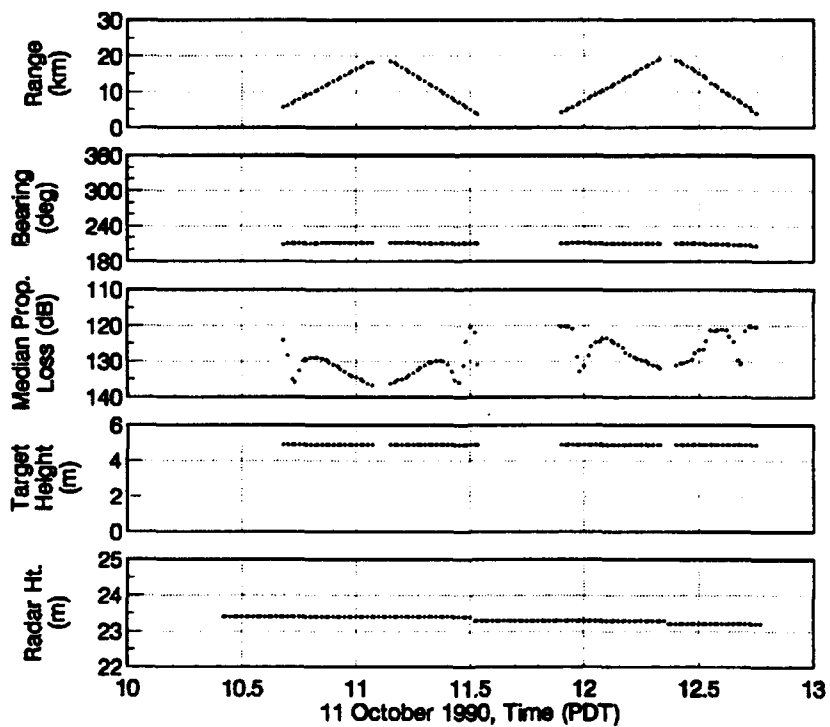


Figure 58. Target bearing from radar, median propagation loss, target and radar heights for 10/11/90.

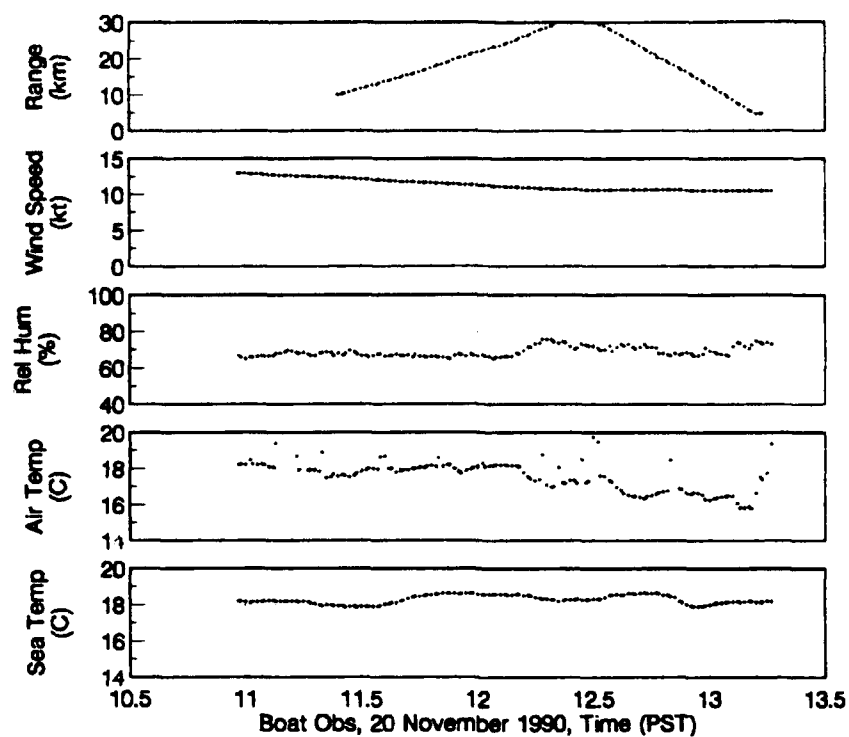


Figure 59. Surface meteorological observations as measured on the boat for 11/20/90.

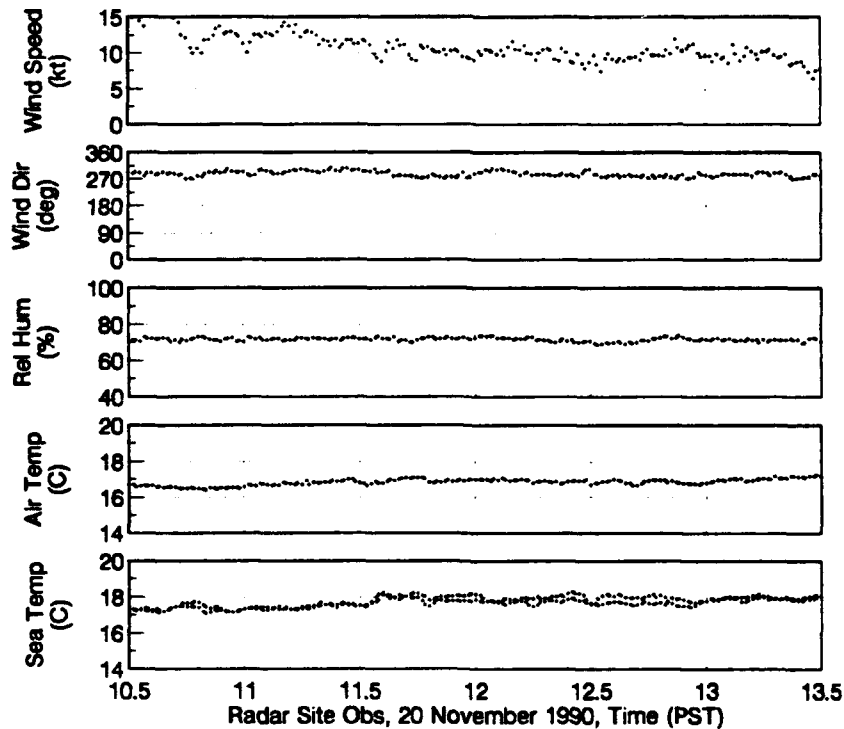


Figure 60. Surface meteorological observations as measured at the F35 site for 11/20/90.

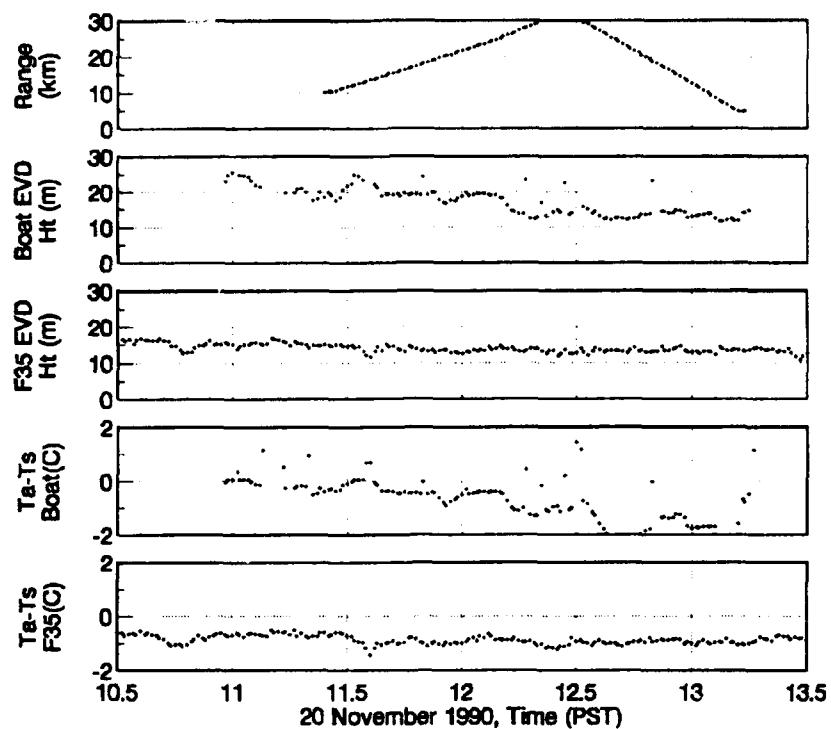


Figure 61. Evaporation duct heights and air-sea temperature differences measured on the boat and at the F35 site for 11/20/90.

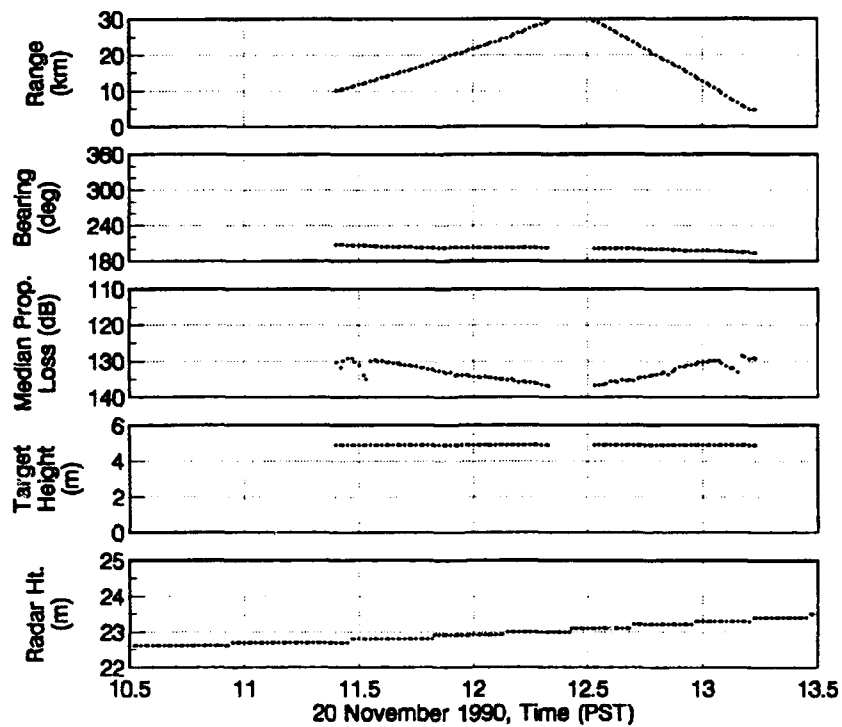


Figure 62. Target bearing from radar, median propagation loss, target and radar heights for 11/20/90.

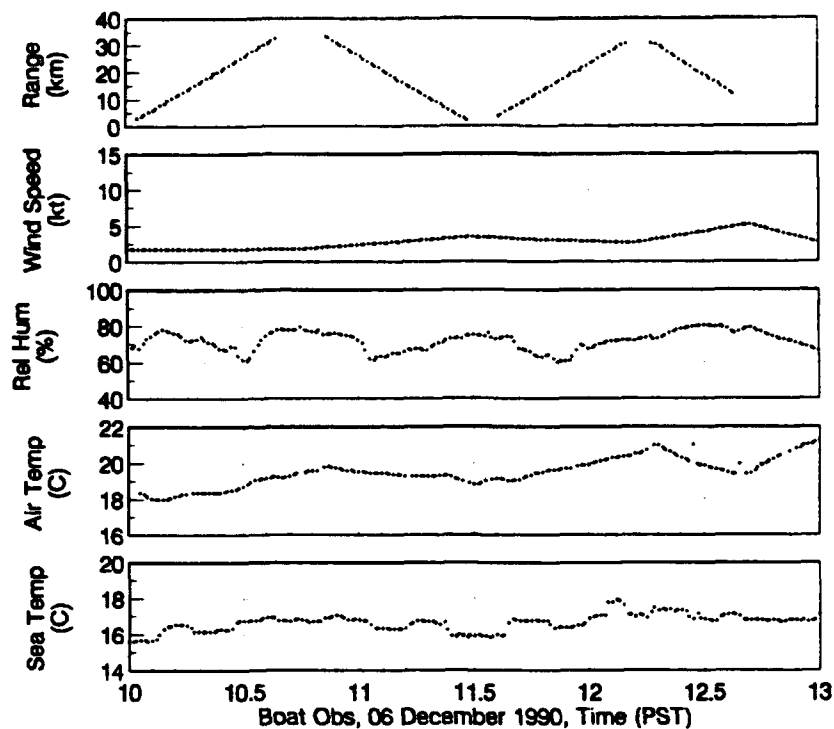


Figure 63. Surface meteorological observations as measured on the boat for 12/06/90.

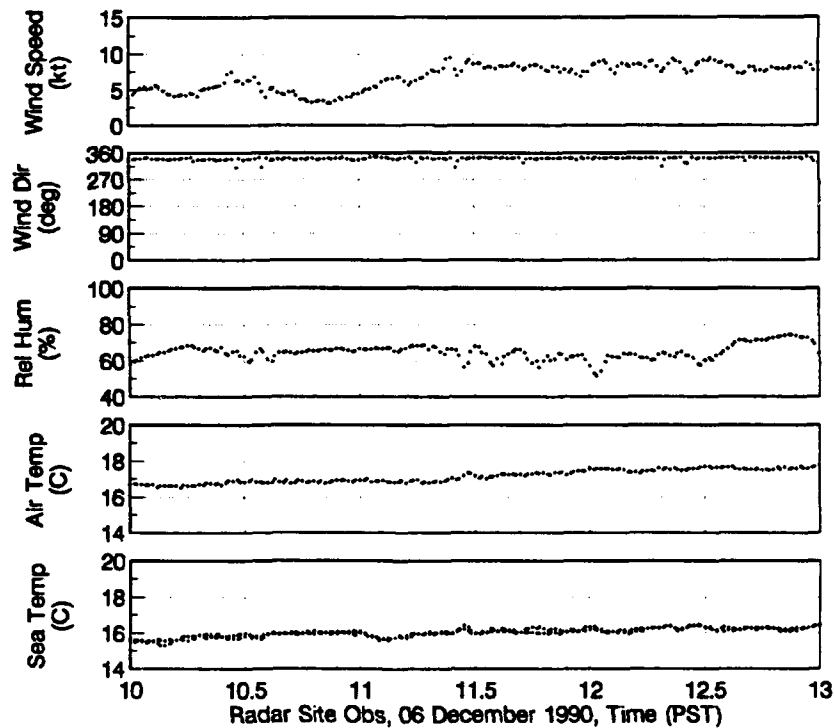


Figure 64. Surface meteorological observations as measured at the F35 site for 12/06/90.

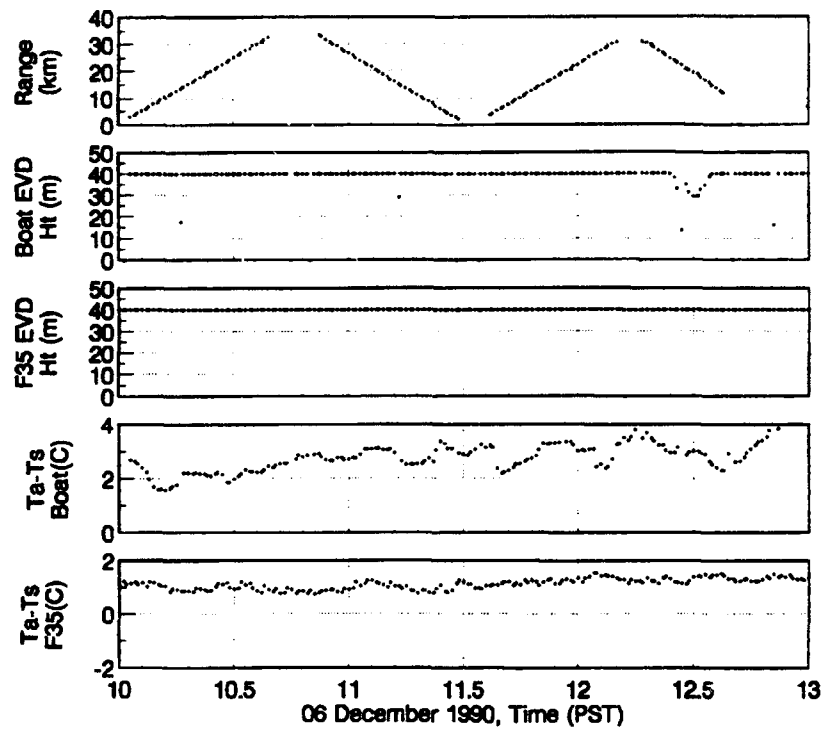


Figure 65. Evaporation duct heights and air-sea temperature differences measured on the boat and at the F35 site for 12/06/90.

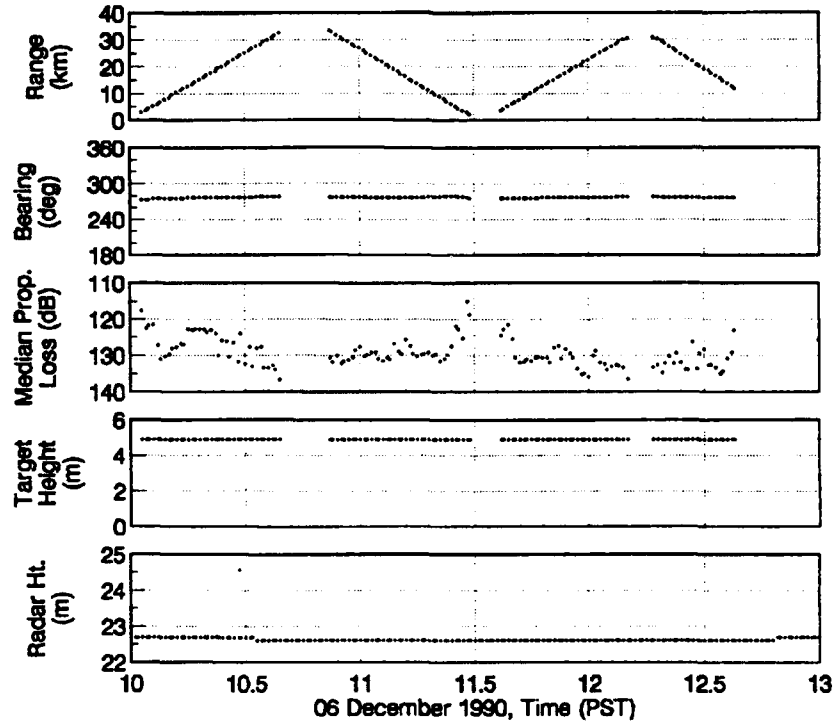


Figure 66. Target bearing from radar, median propagation loss, target and radar heights for 12/06/90.

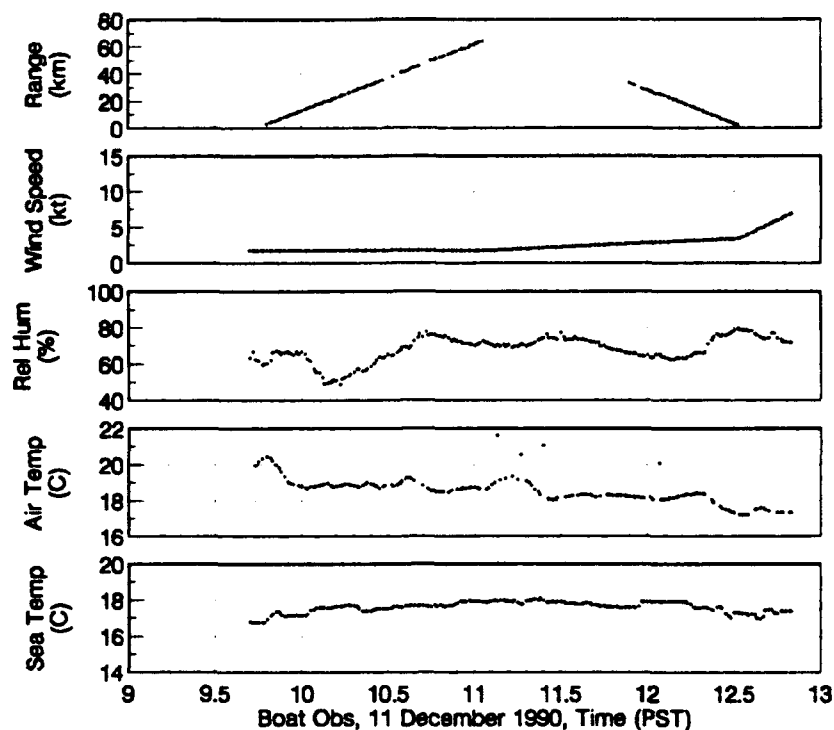


Figure 67. Surface meteorological observations as measured on the boat for 12/11/90.

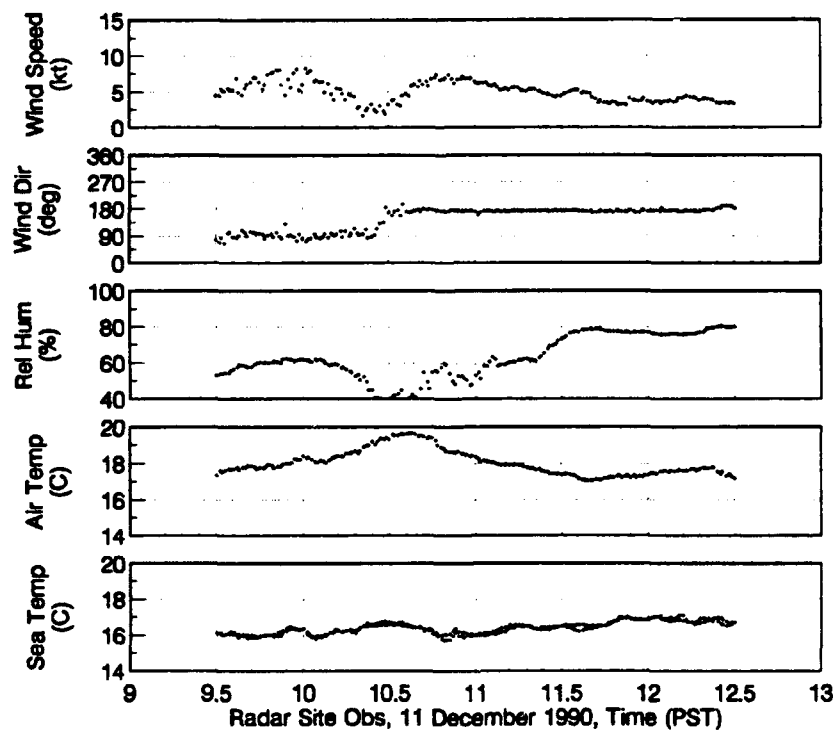


Figure 68. Surface meteorological observations as measured at the F35 site for 12/11/90.

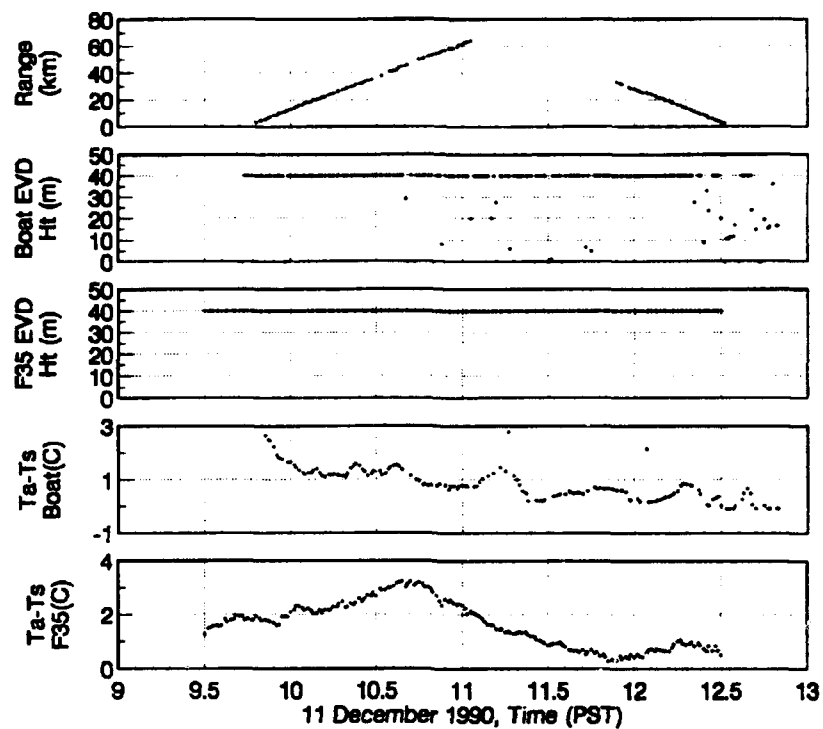


Figure 69. Evaporation duct heights and air-sea temperature differences measured on the boat and at the F35 site for 12/11/90.

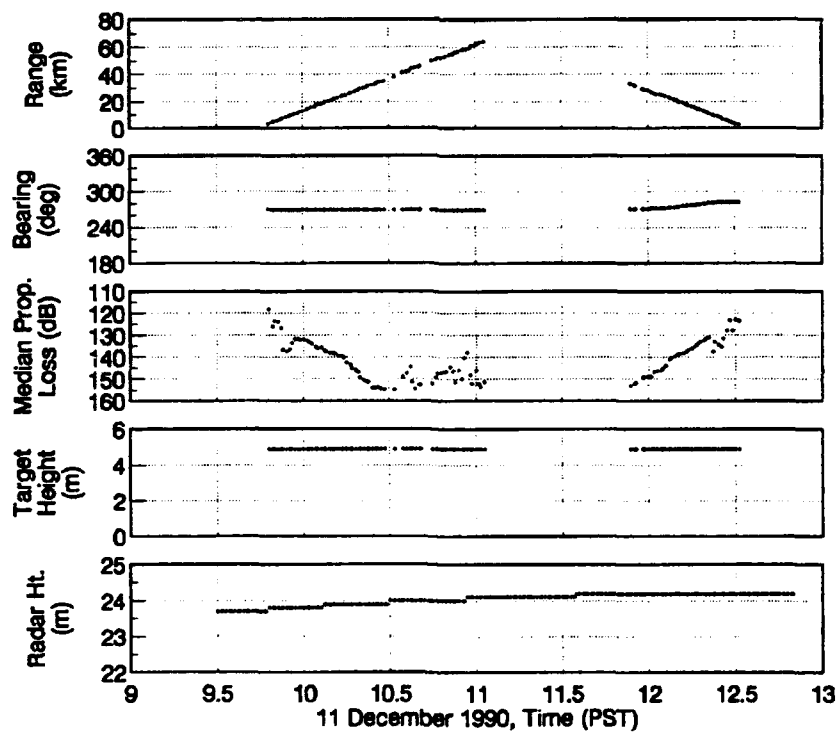


Figure 70. Target bearing from radar, median propagation loss, target and radar heights for 12/11/90.

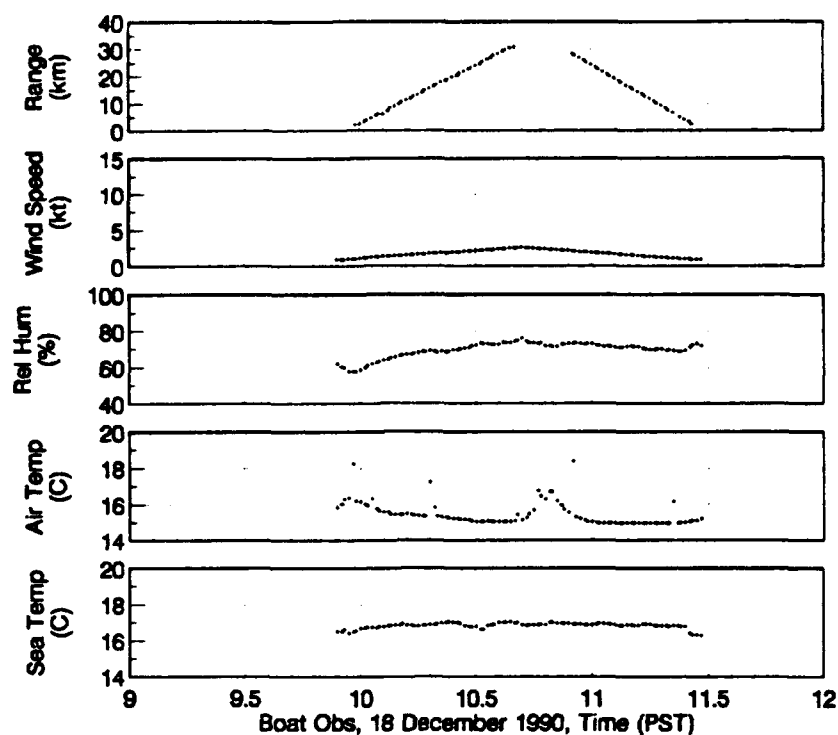


Figure 71. Surface meteorological observations as measured on the boat for 12/18/90.

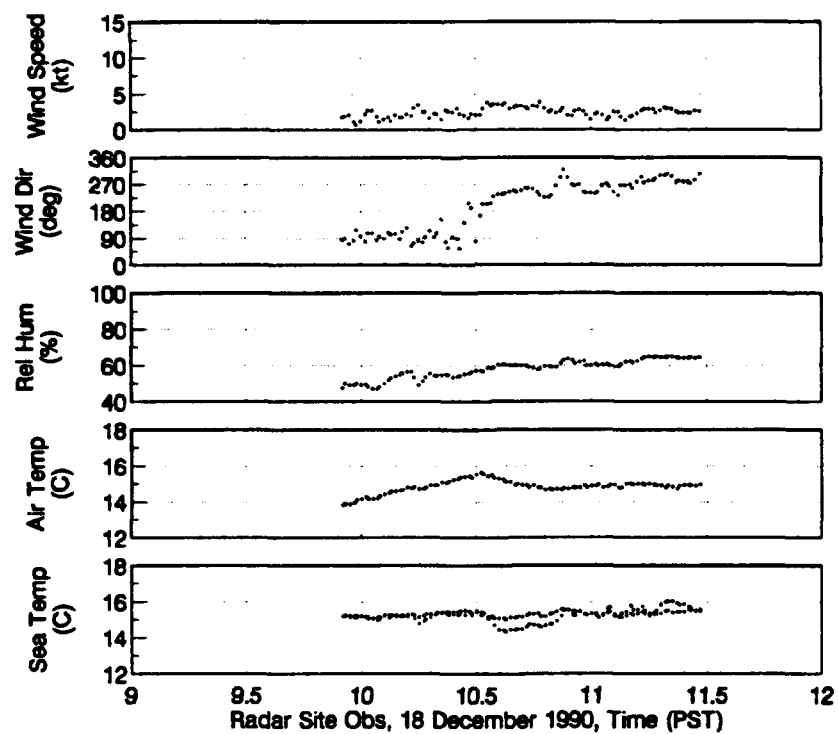


Figure 72. Surface meteorological observations as measured at the F35 site for 12/18/90.

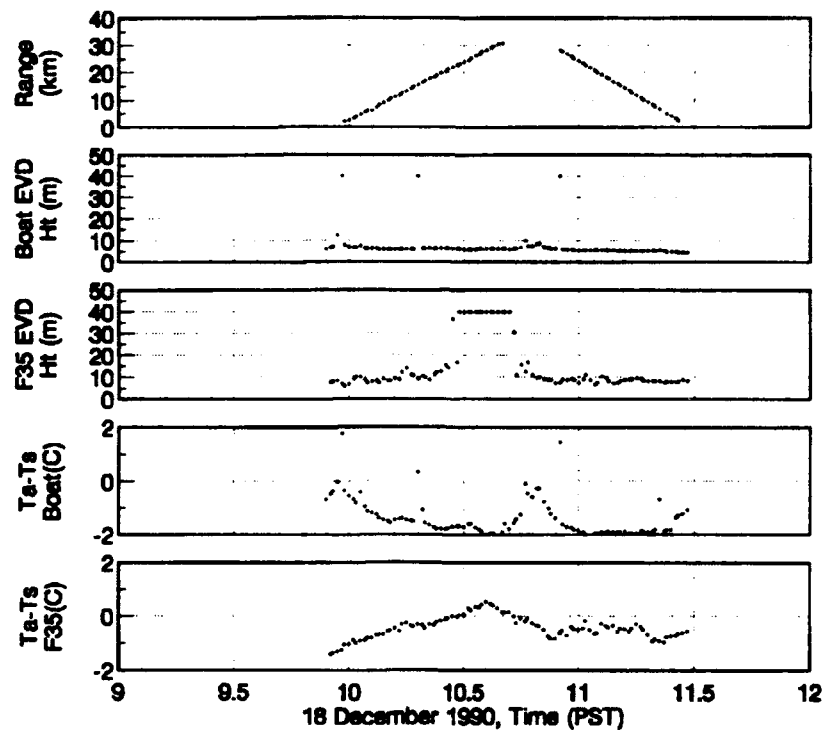


Figure 73. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 12/18/90.

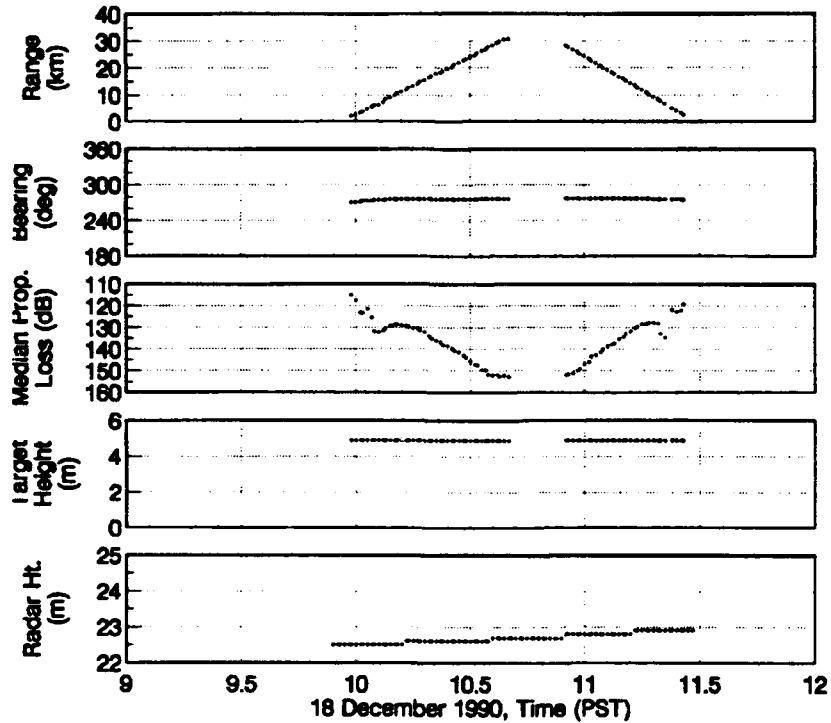


Figure 74. Target bearing from radar, median propagation loss, target and radar heights for 12/18/90.

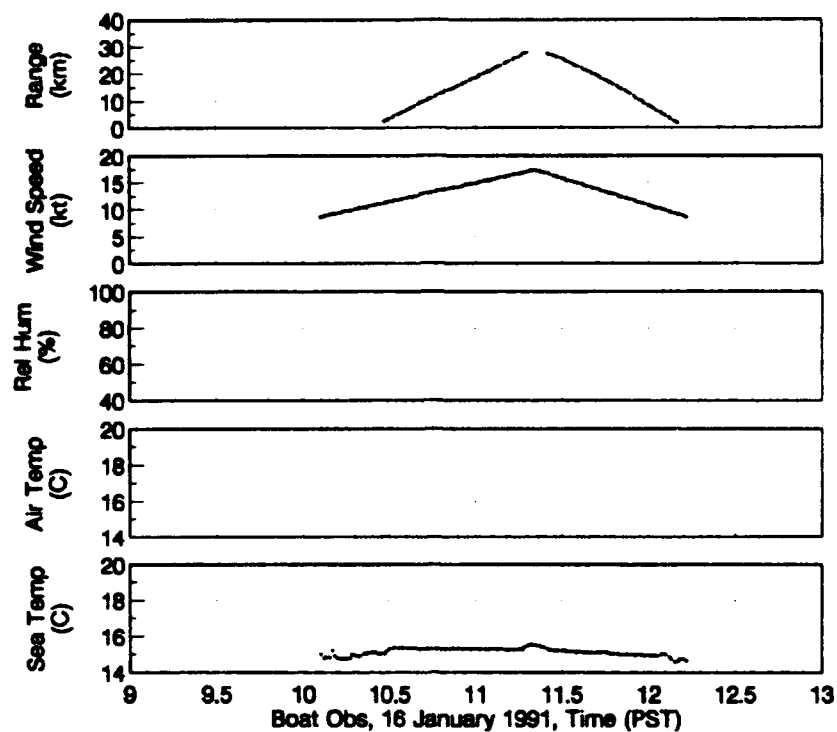


Figure 75. Surface meteorological observations as measured on the boat for 01/16/91.

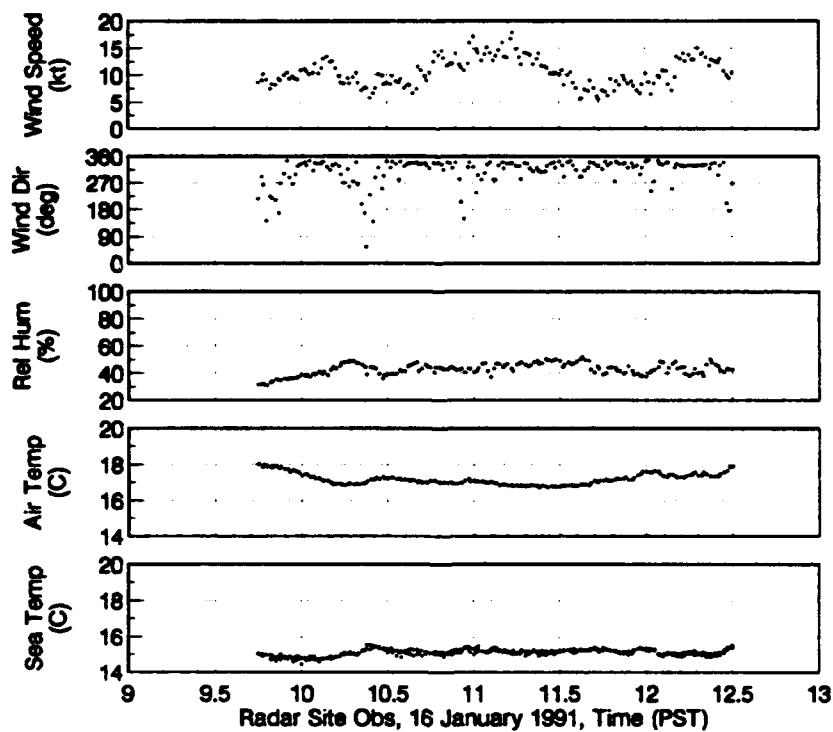


Figure 76. Surface meteorological observations as measured at the F35 site for 01/16/91.

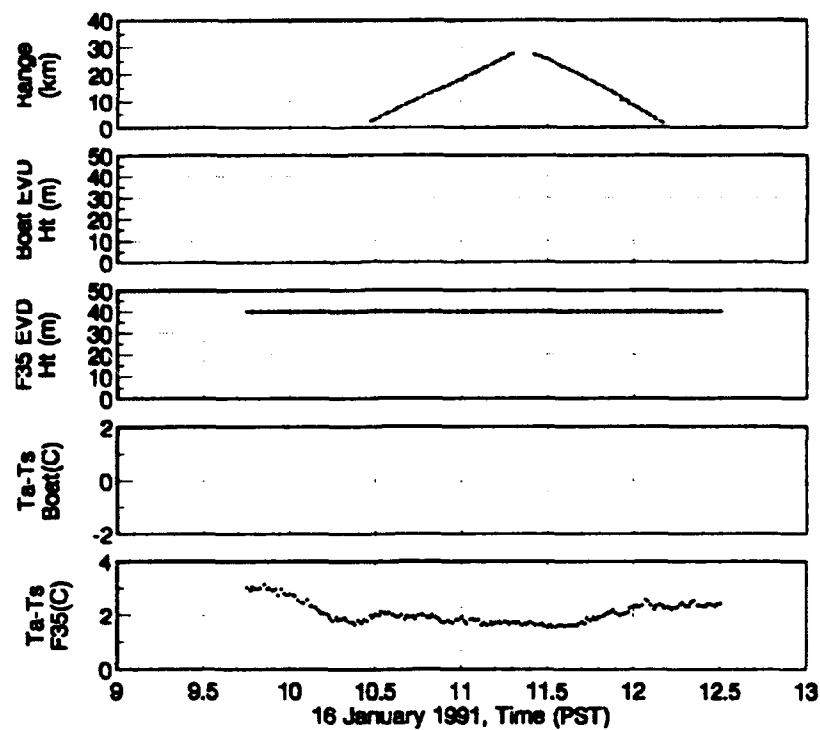


Figure 77. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 01/16/91.

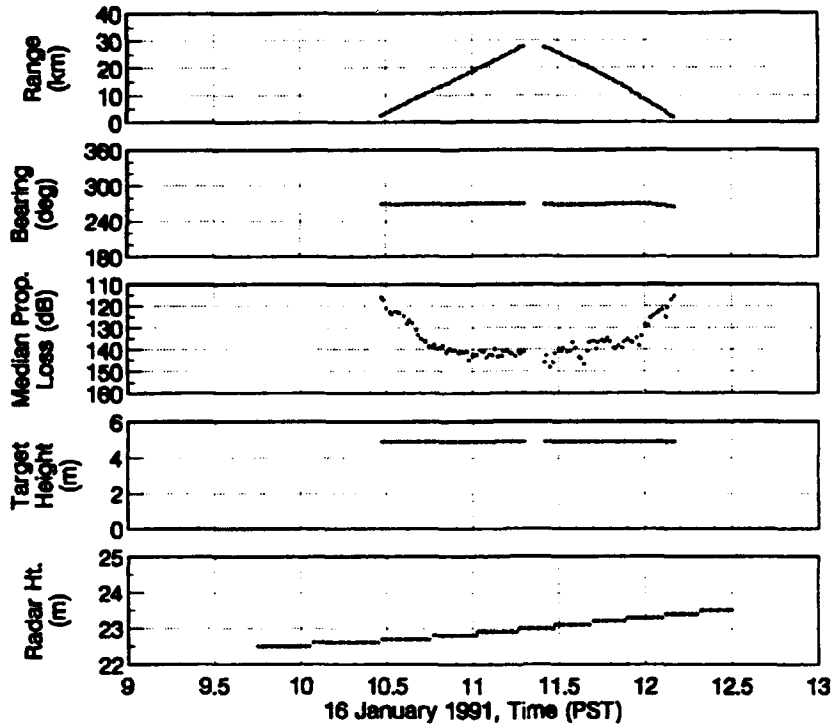


Figure 78. Target bearing from radar, median propagation loss, target and radar heights for 01/16/91.

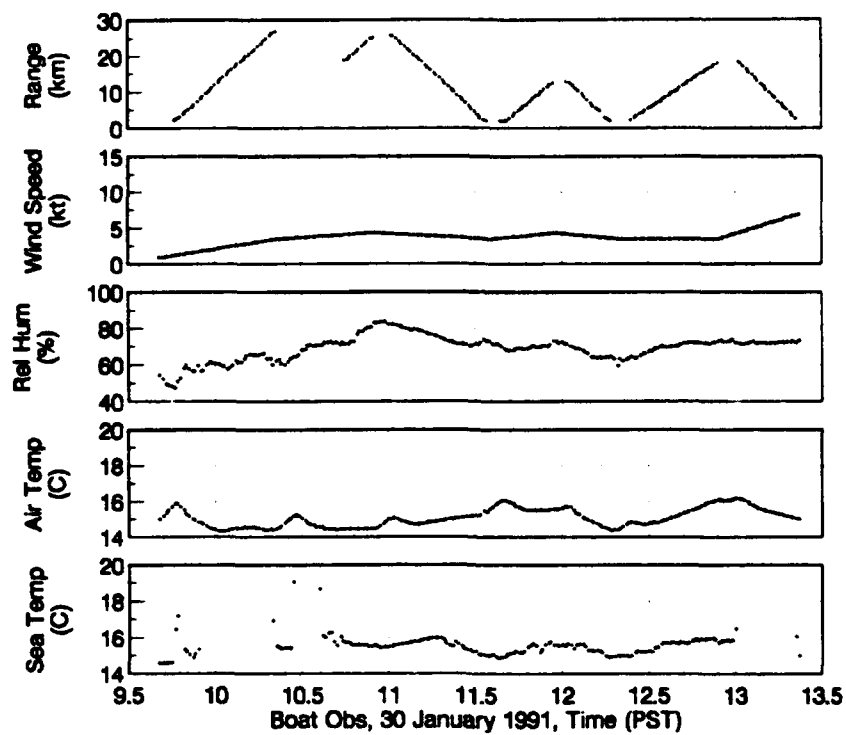


Figure 79. Surface meteorological observations as measured on the boat for 01/30/91.

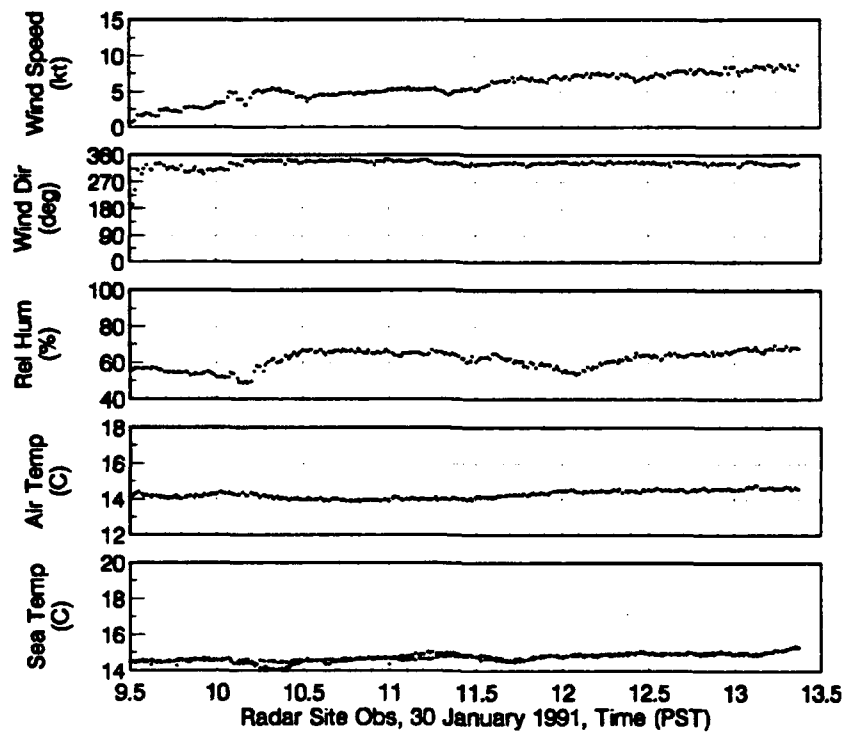


Figure 80. Surface meteorological observations as measured at the F35 site for 01/30/91.

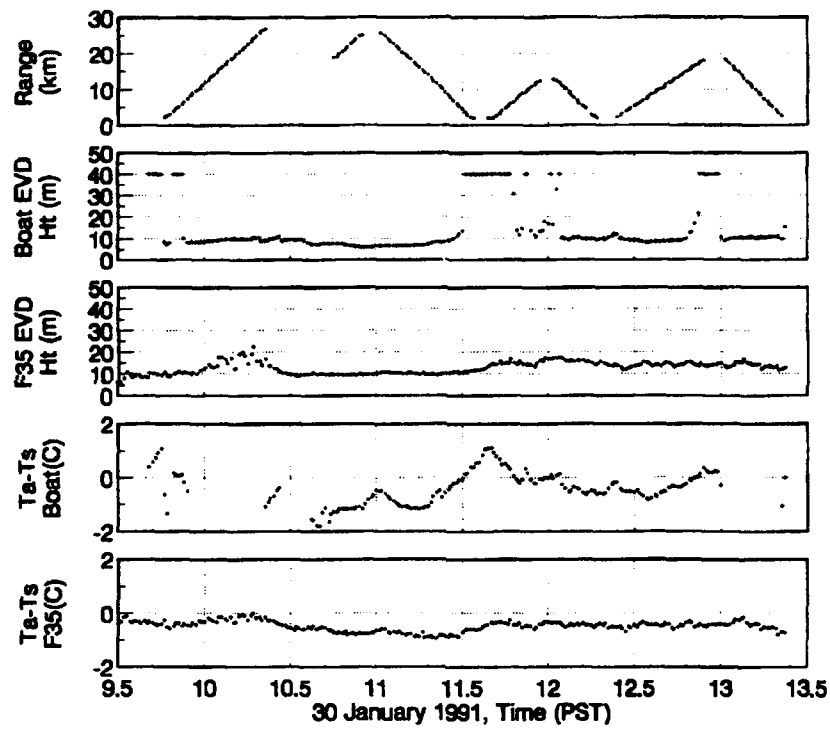


Figure 81. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 01/30/91.

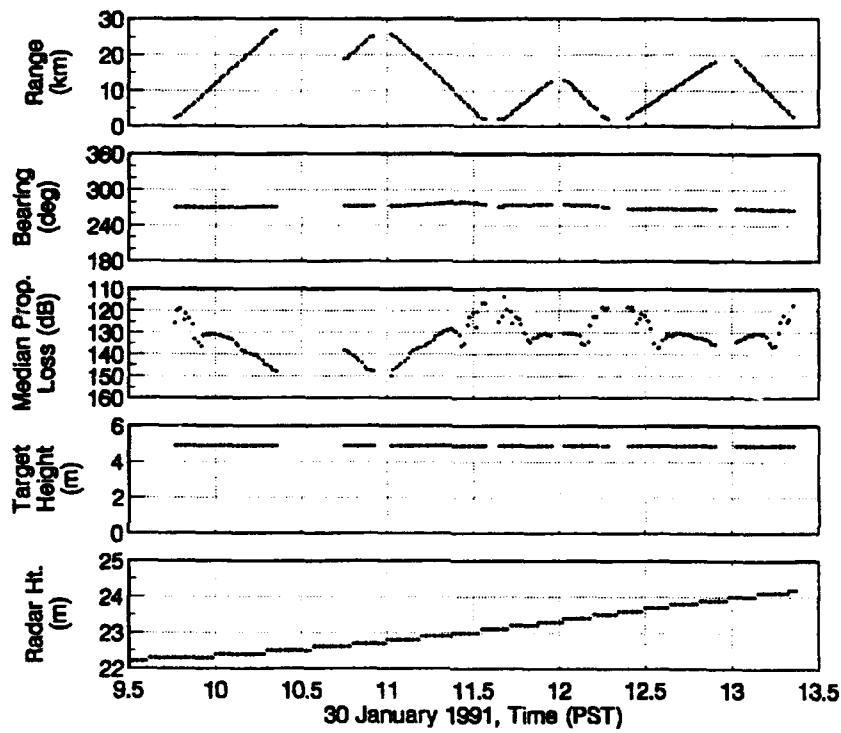


Figure 82. Target bearing from radar, median propagation loss, target and radar heights for 01/30/91.

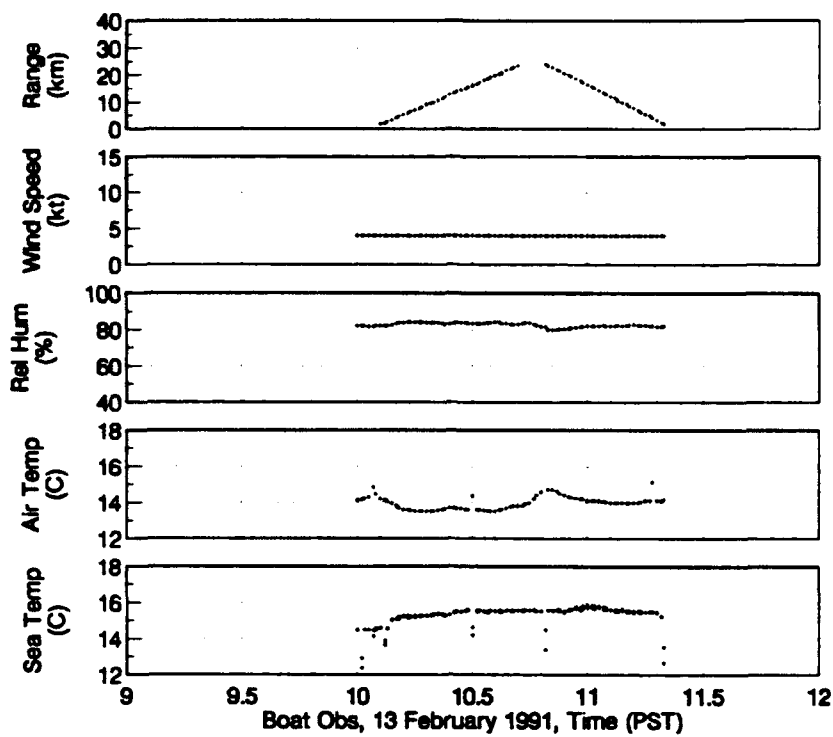


Figure 83. Surface meteorological observations as measured on the boat for 02/13/91.

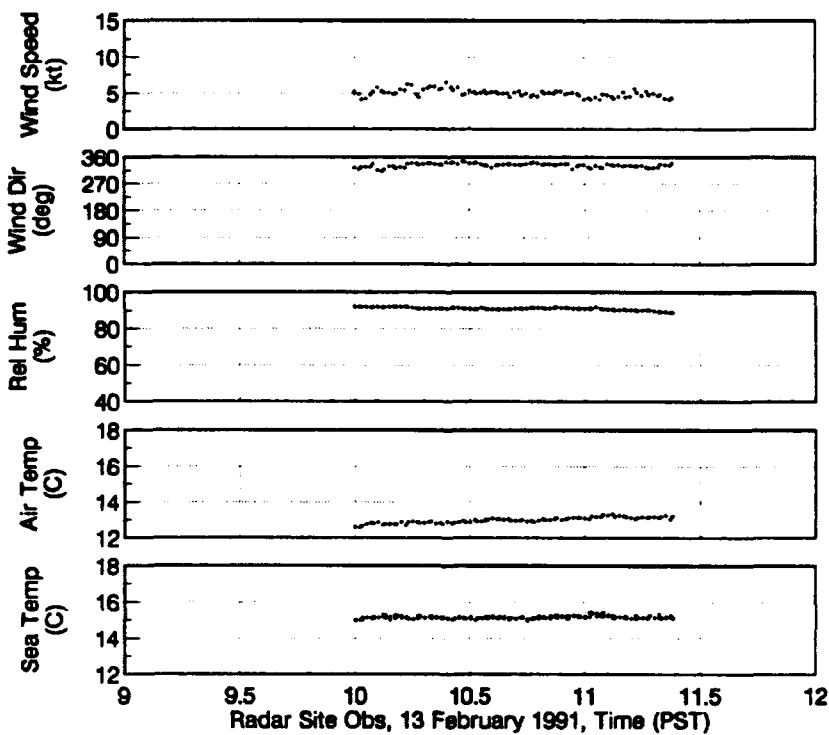


Figure 84. Surface meteorological observations as measured at the F35 site for 02/13/91.

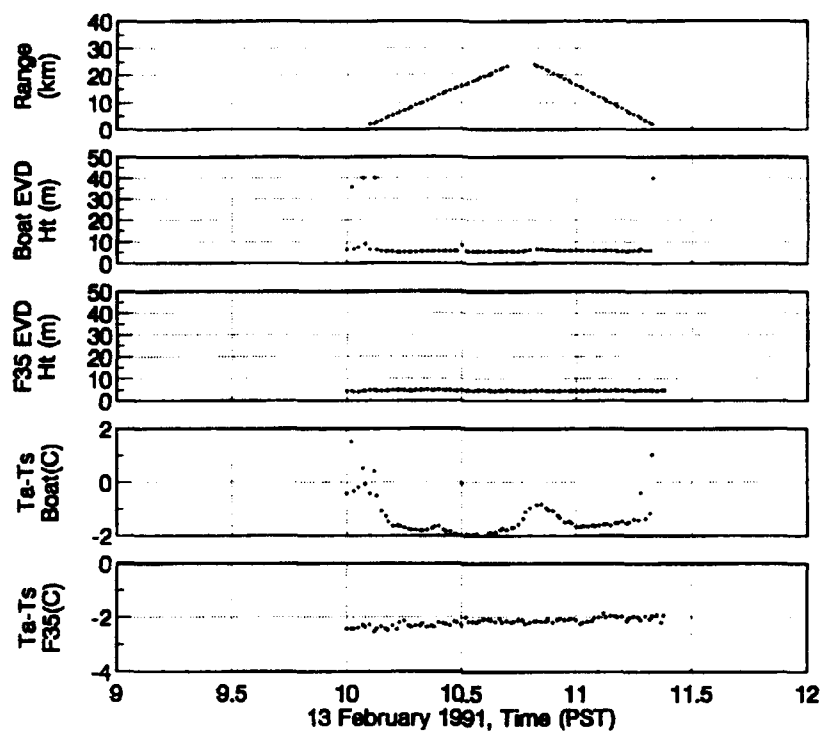


Figure 85. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 02/13/91.

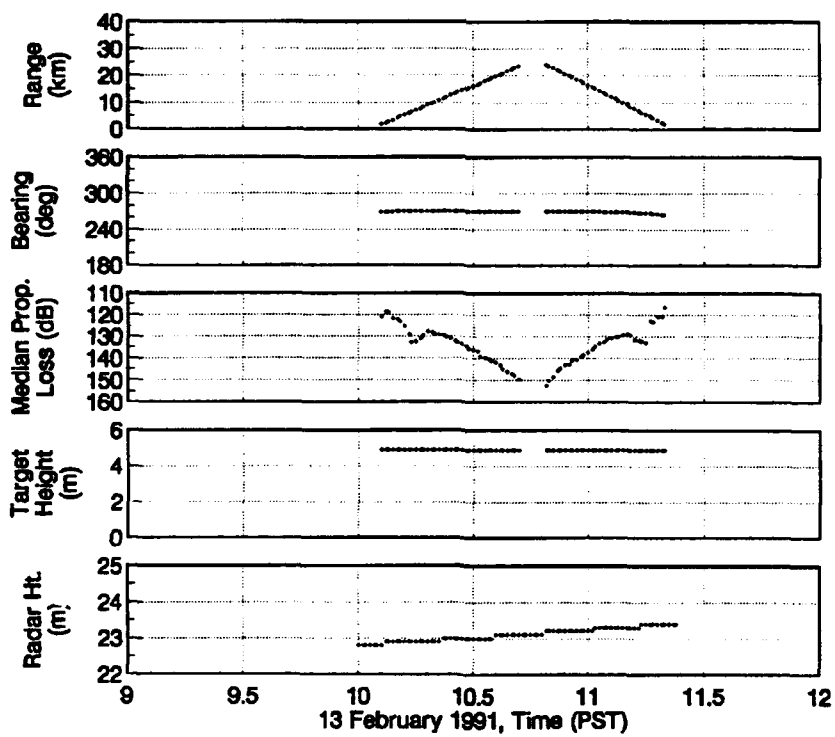


Figure 86. Target bearing from radar, median propagation loss, target and radar heights for 02/13/91.

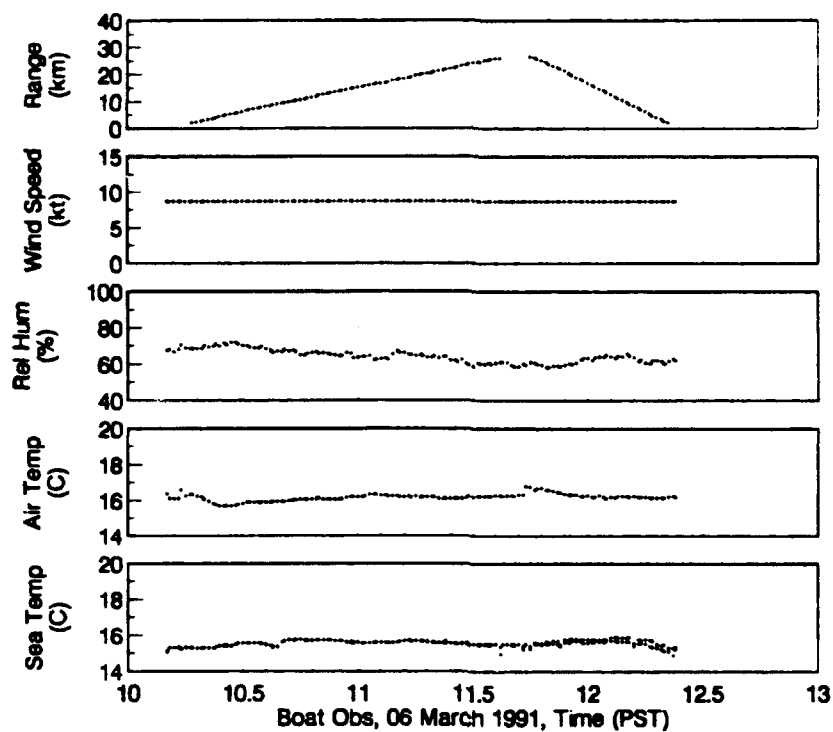


Figure 87. Surface meteorological observations as measured on the boat for 03/06/91.

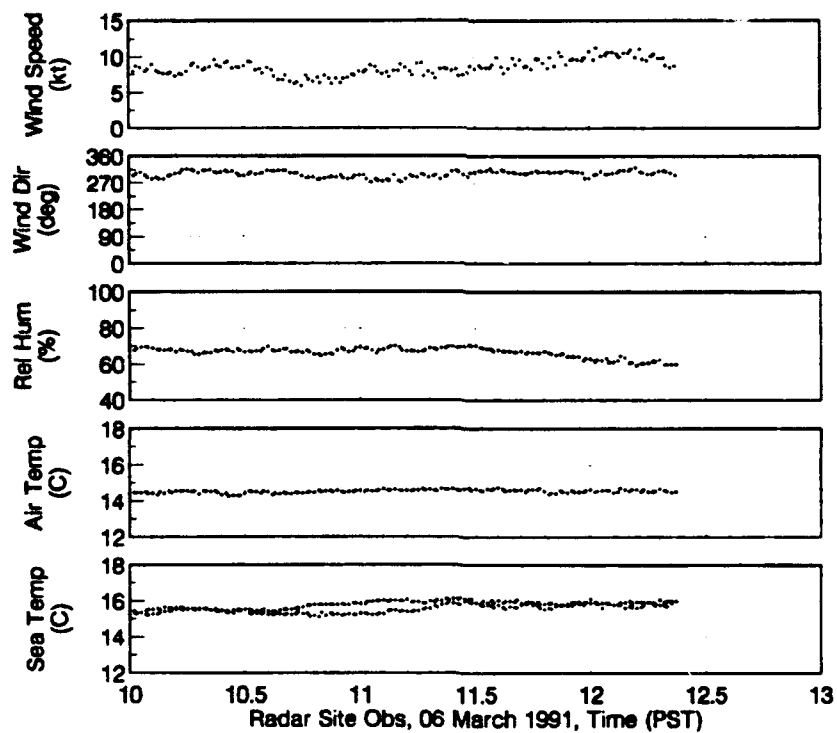


Figure 88. Surface meteorological observations as measured at the F35 site for 03/06/91.

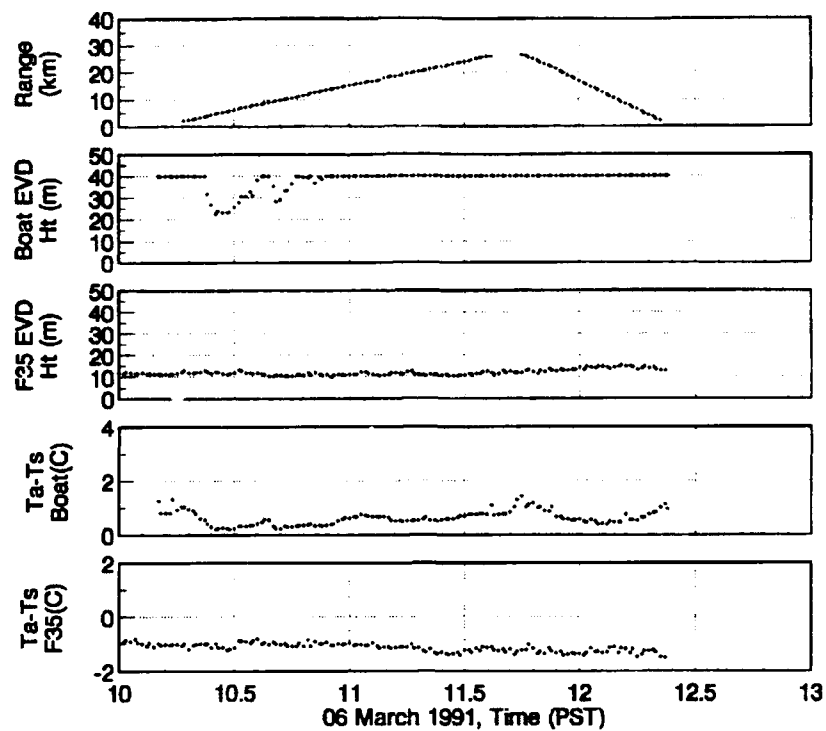


Figure 89. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 03/06/91.

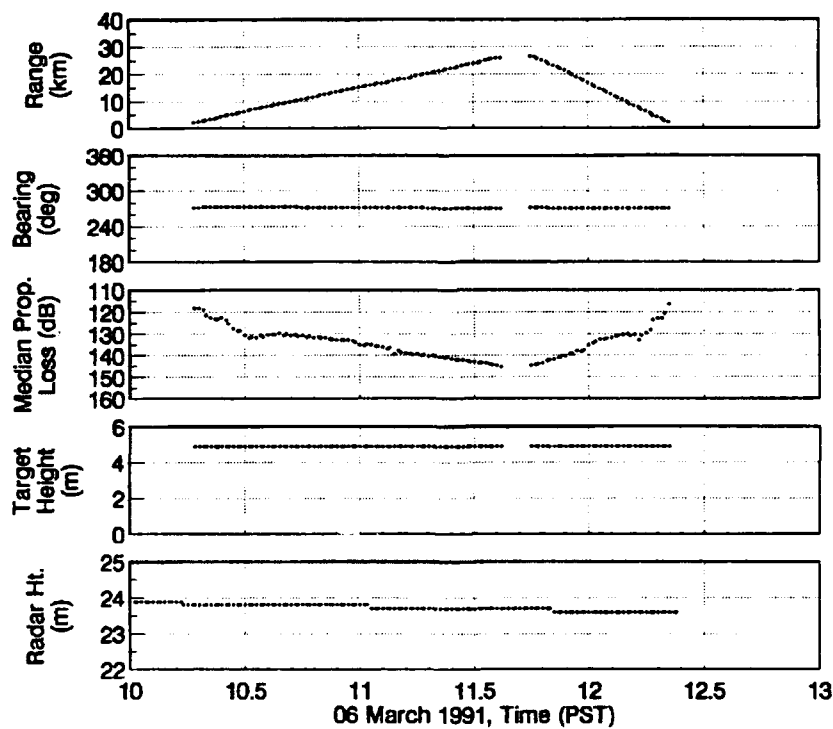


Figure 90. Target bearing from radar, median propagation loss, target and radar heights for 03/06/91.

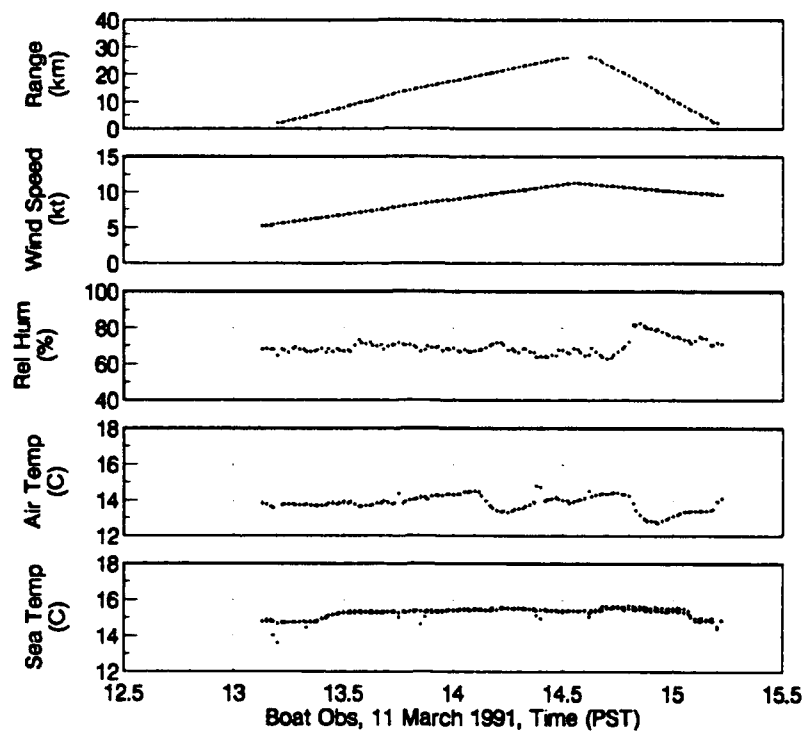


Figure 91. Surface meteorological observations as measured on the boat for 03/11/91.

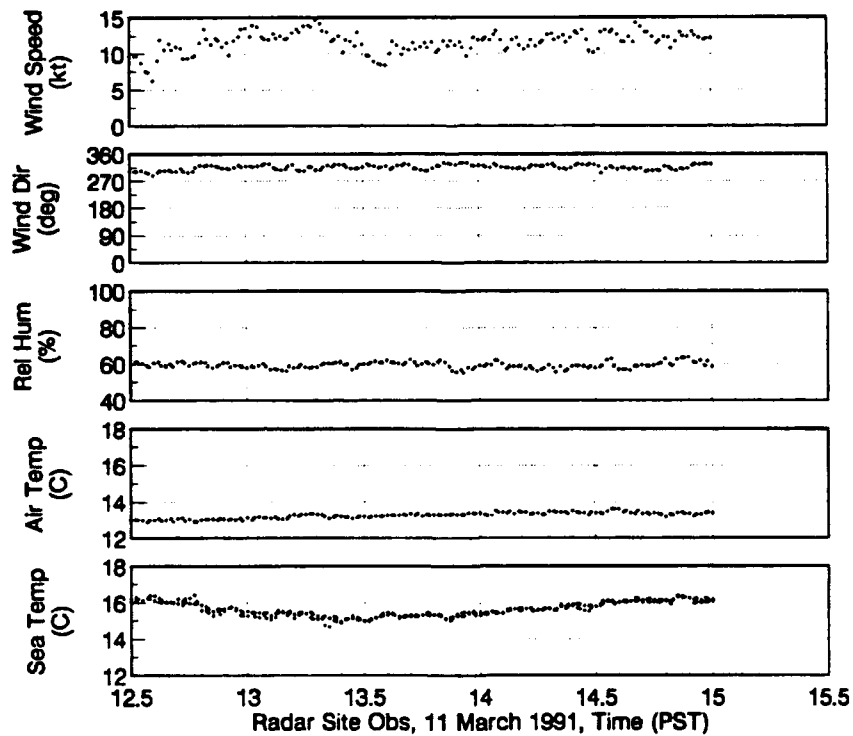


Figure 92. Surface meteorological observations as measured at the F35 site for 03/11/91.

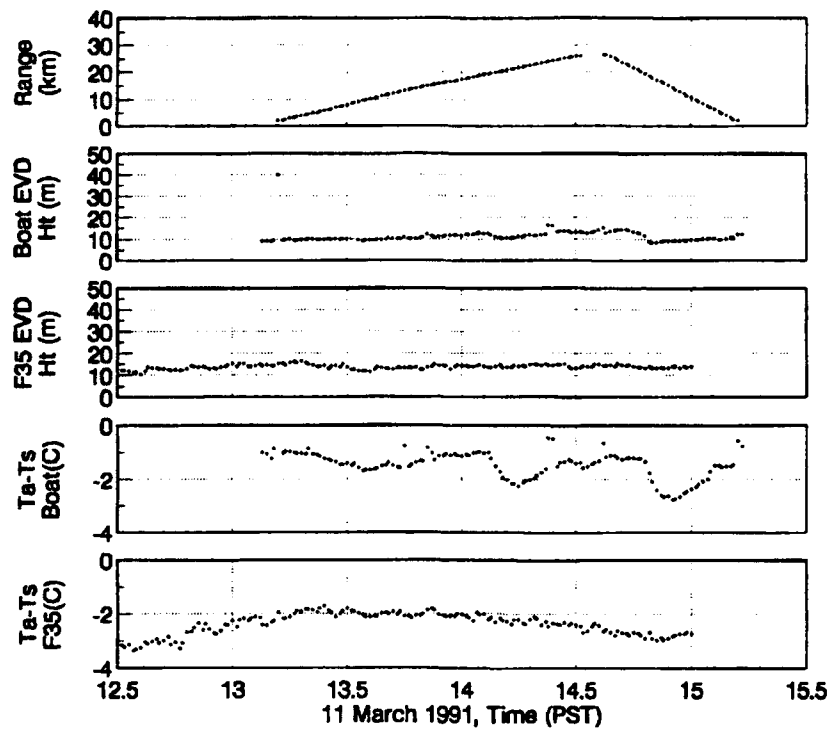


Figure 93. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 03/11/91.

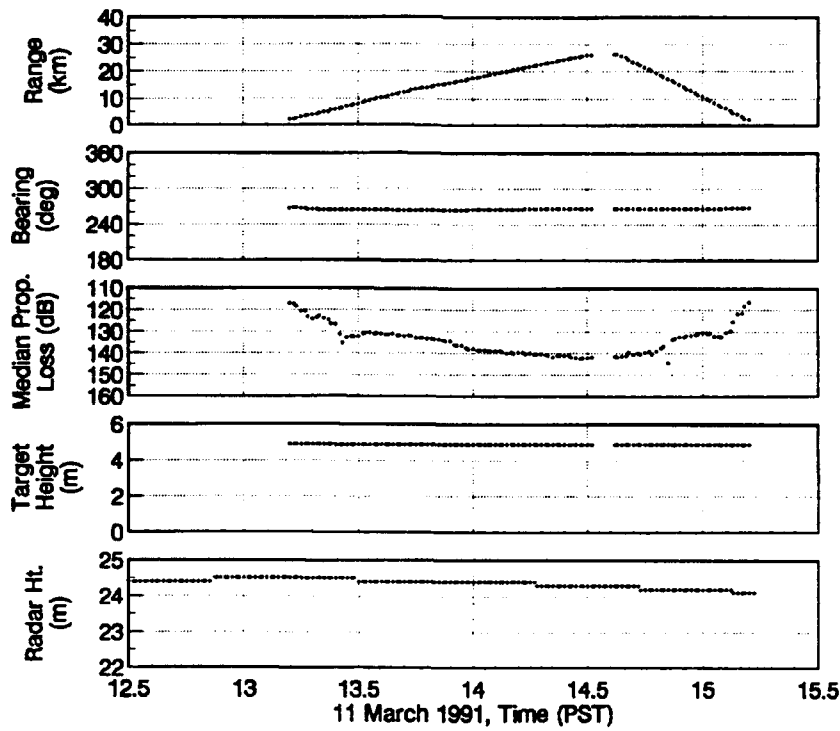


Figure 94. Target bearing from radar, median propagation loss, target and radar heights for 03/11/91.

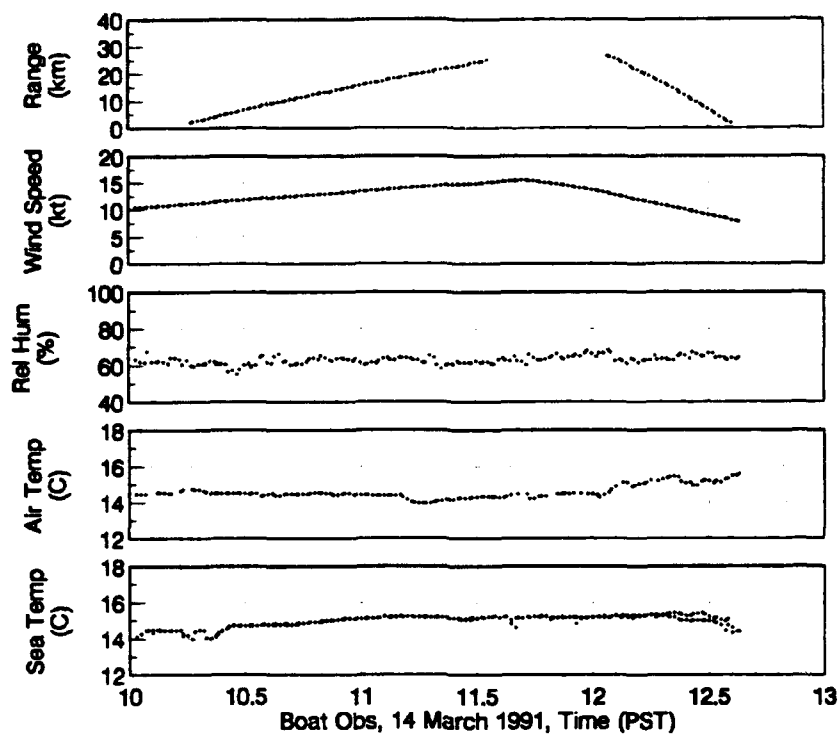


Figure 95. Surface meteorological observations as measured on the boat for 03/14/91.

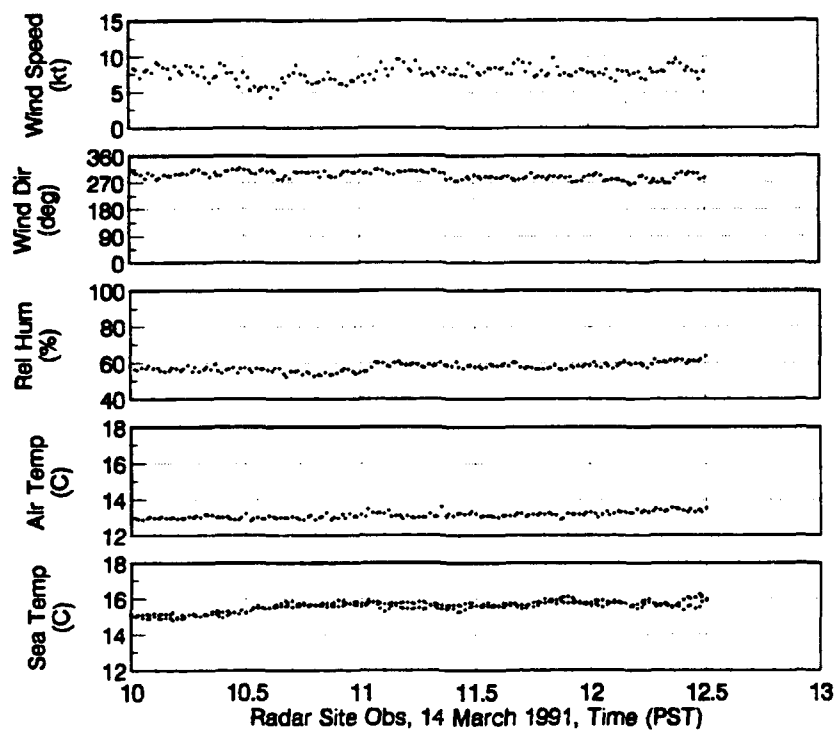


Figure 96. Surface meteorological observations as measured at the F35 site for 03/14/91.

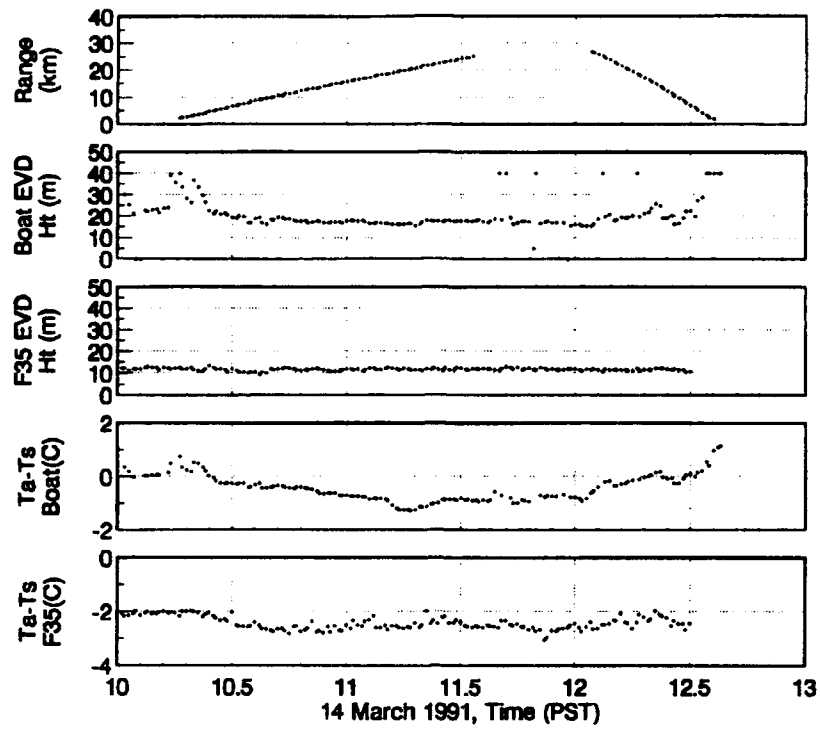


Figure 97. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 03/14/91.

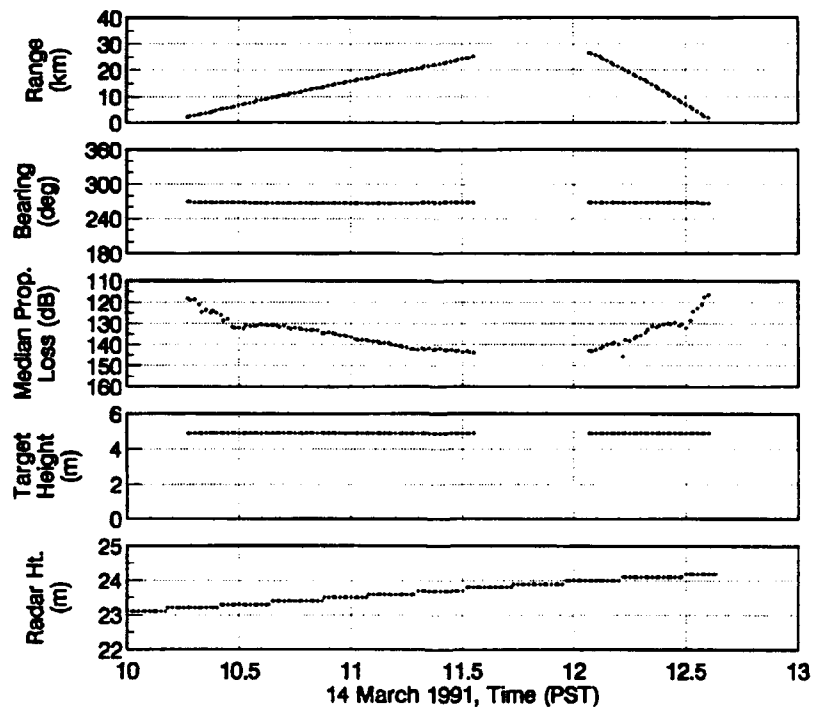


Figure 98. Target bearing from radar, median propagation loss, target and radar heights for 03/14/91.

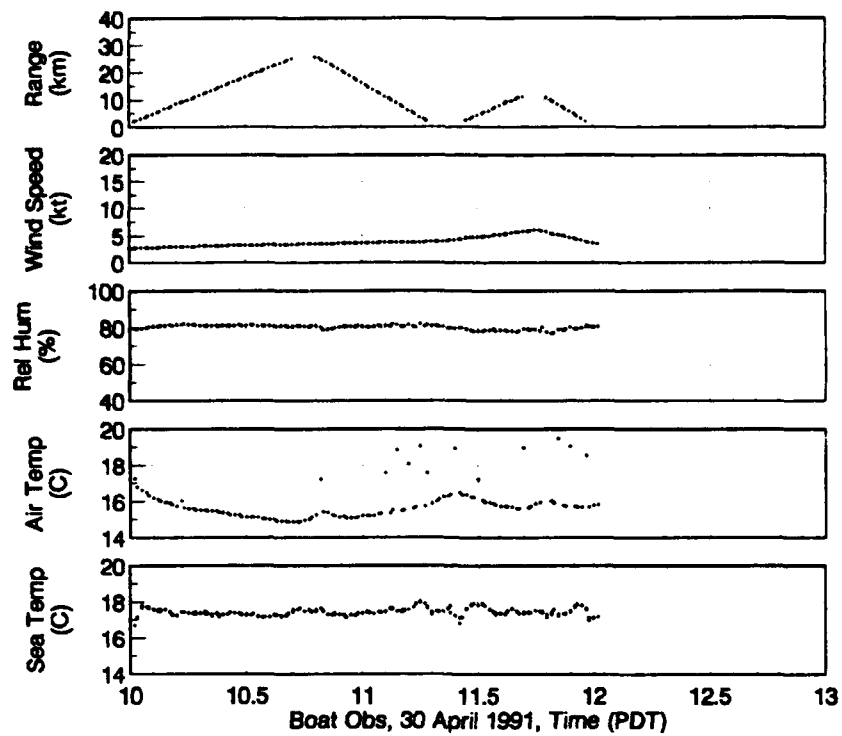


Figure 99. Surface meteorological observations as measured on the boat for 04/30/91.

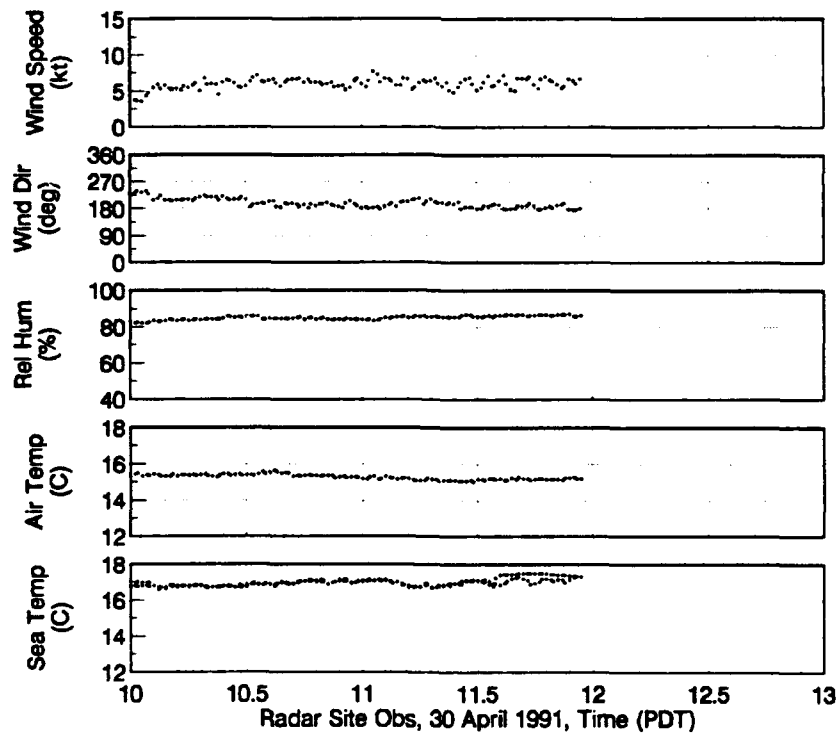


Figure 100. Surface meteorological observations as measured at the F35 site for 04/30/91.

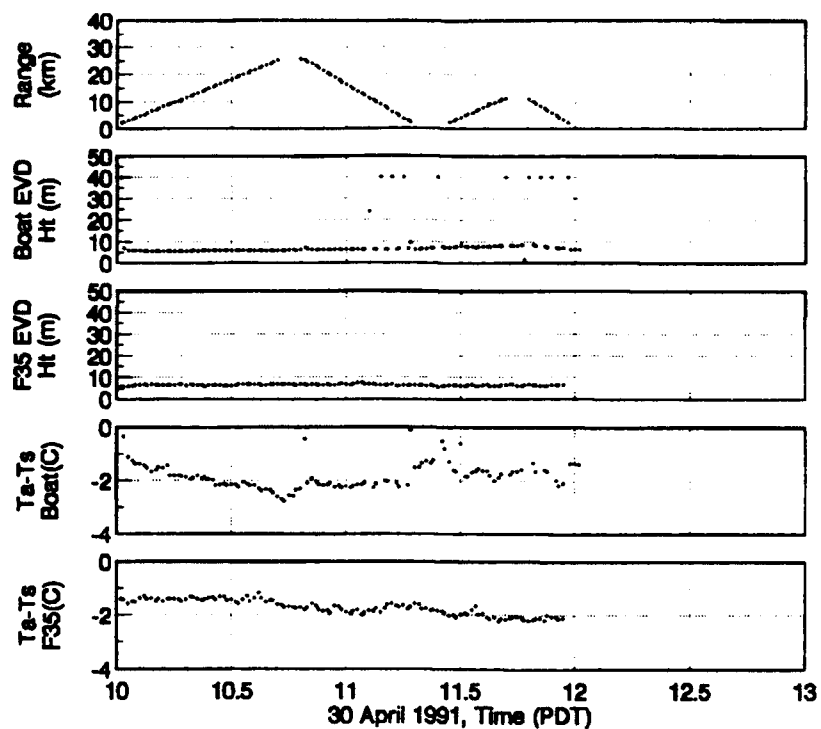


Figure 101. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 04/30/91.

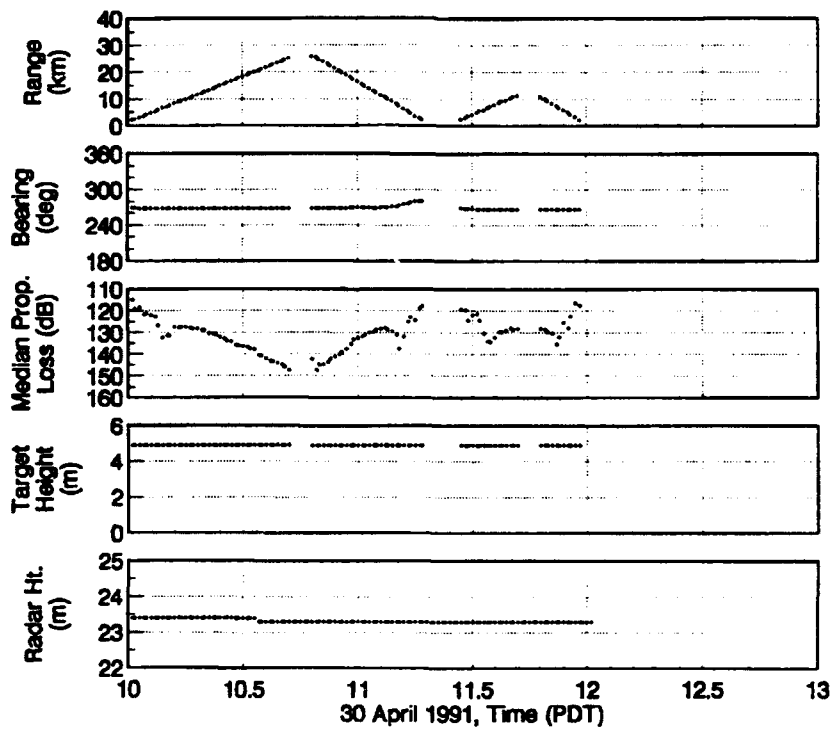


Figure 102. Target bearing from radar, median propagation loss, target and radar heights for 04/30/91.

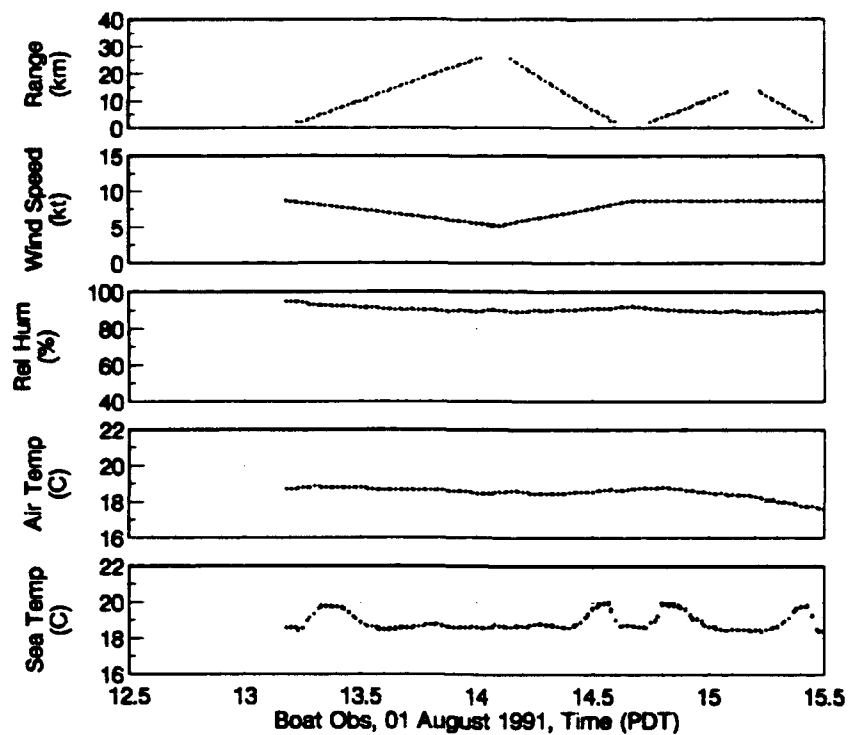


Figure 103. Surface meteorological observations as measured on the boat for 08/01/91.

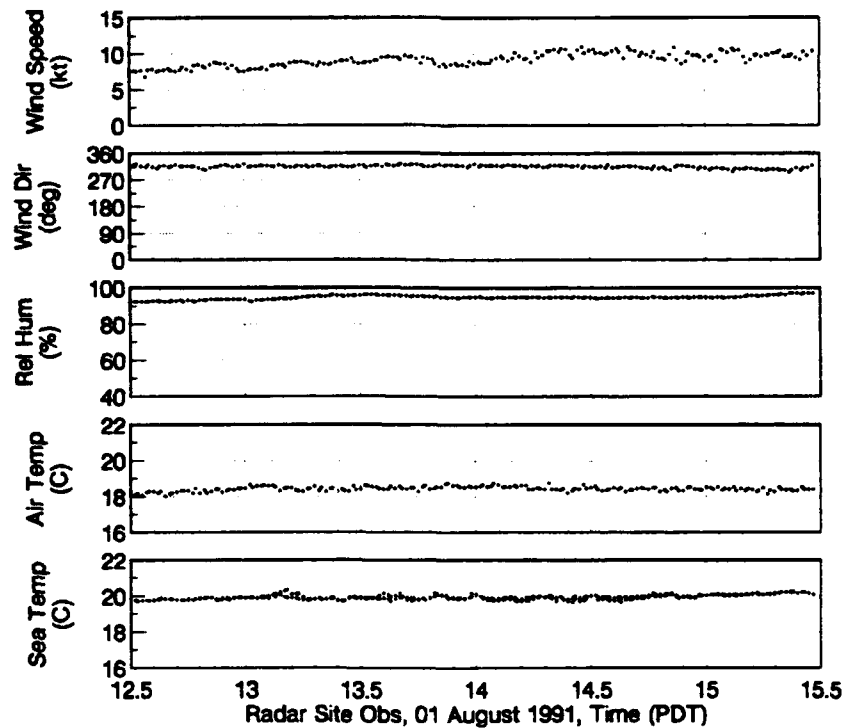


Figure 104. Surface meteorological observations as measured at the F35 site for 08/01/91.

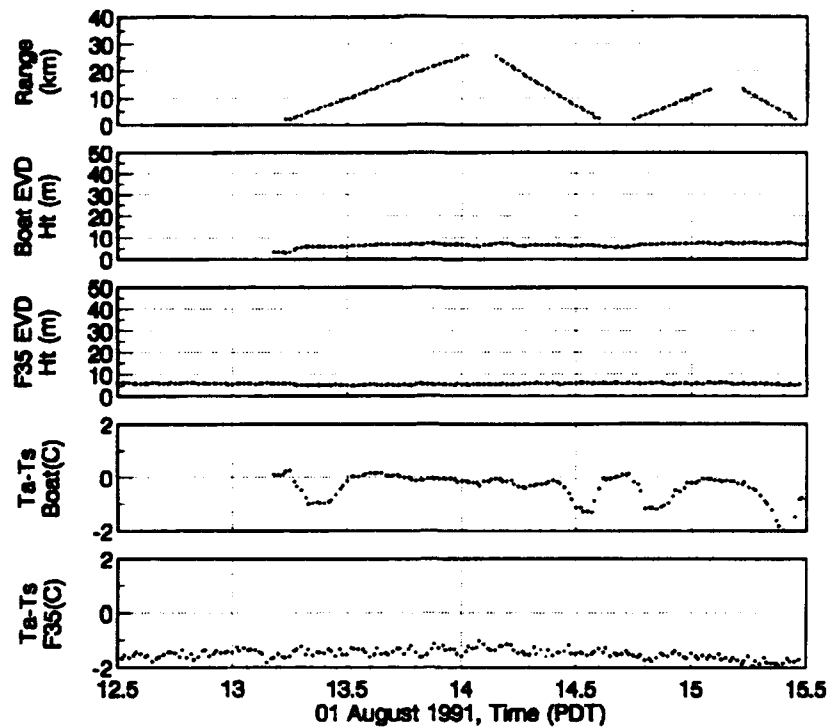


Figure 105. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 08/01/91.

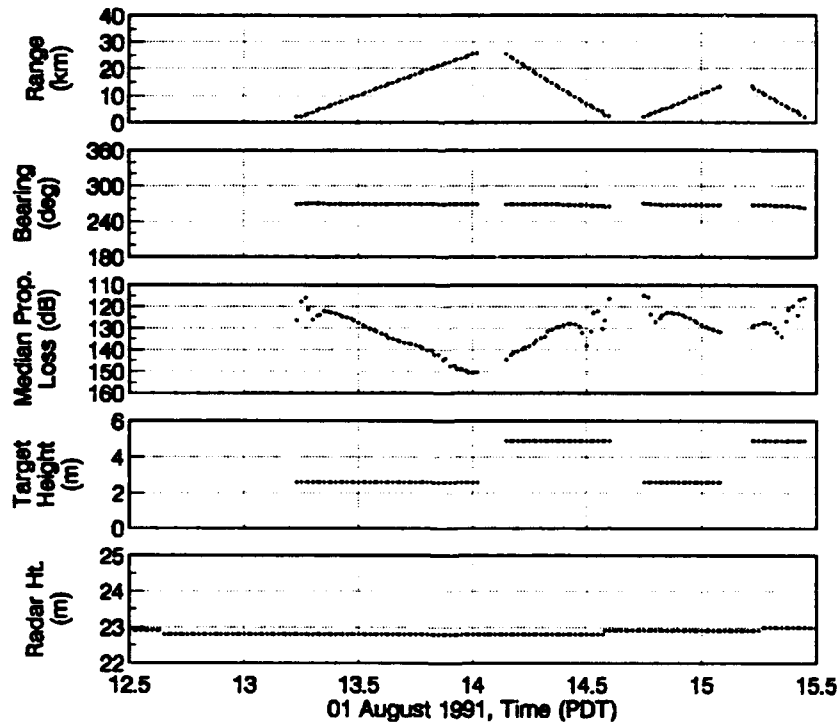


Figure 106. Target bearing from radar, median propagation loss, target and radar heights for 08/01/91.

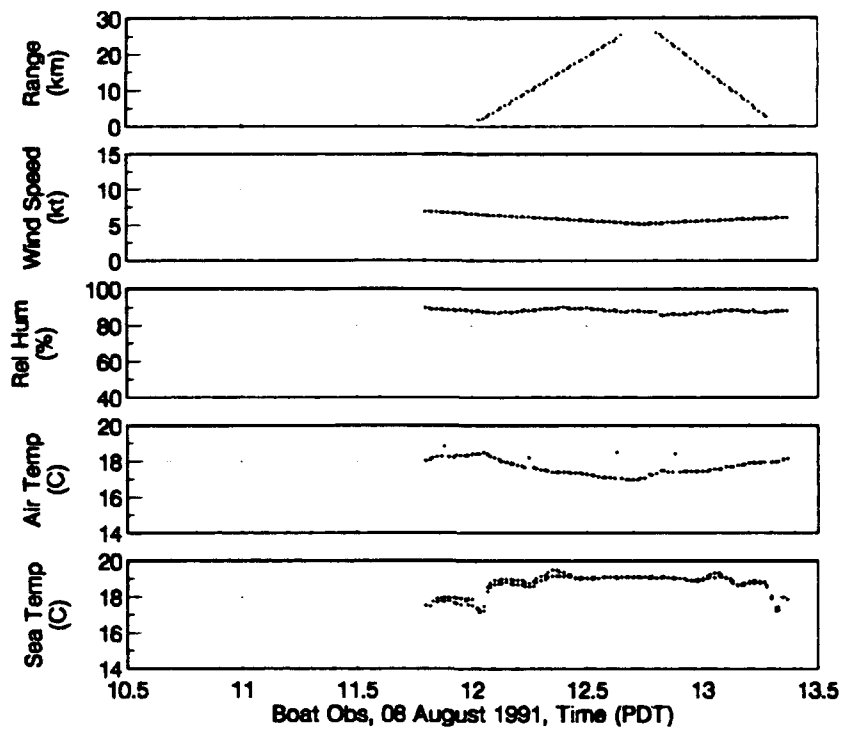


Figure 107. Surface meteorological observations as measured on the boat for 08/08/91.

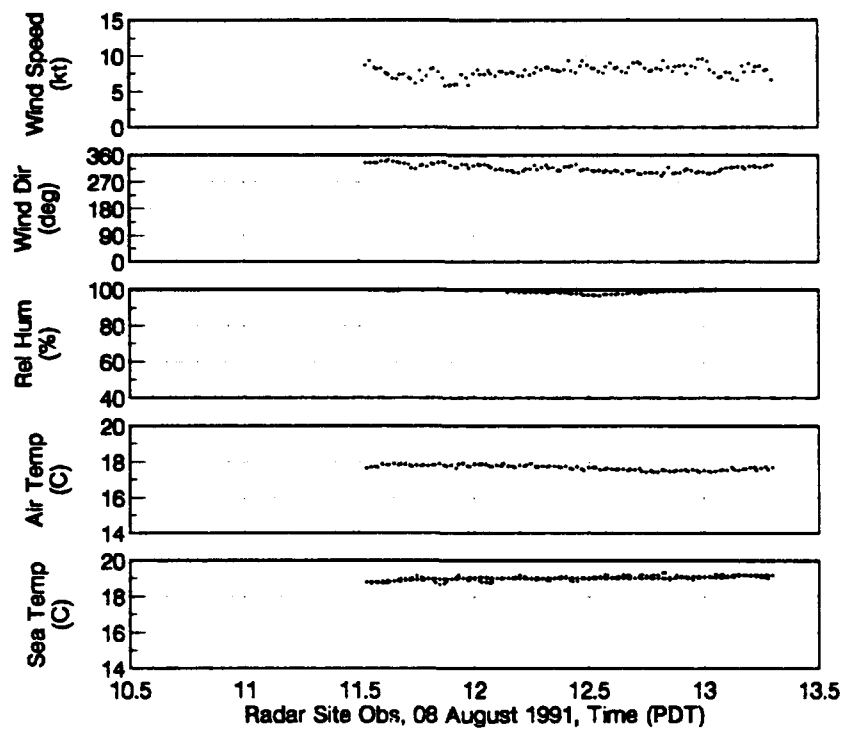


Figure 108. Surface meteorological observations as measured at the F35 site for 08/08/91.

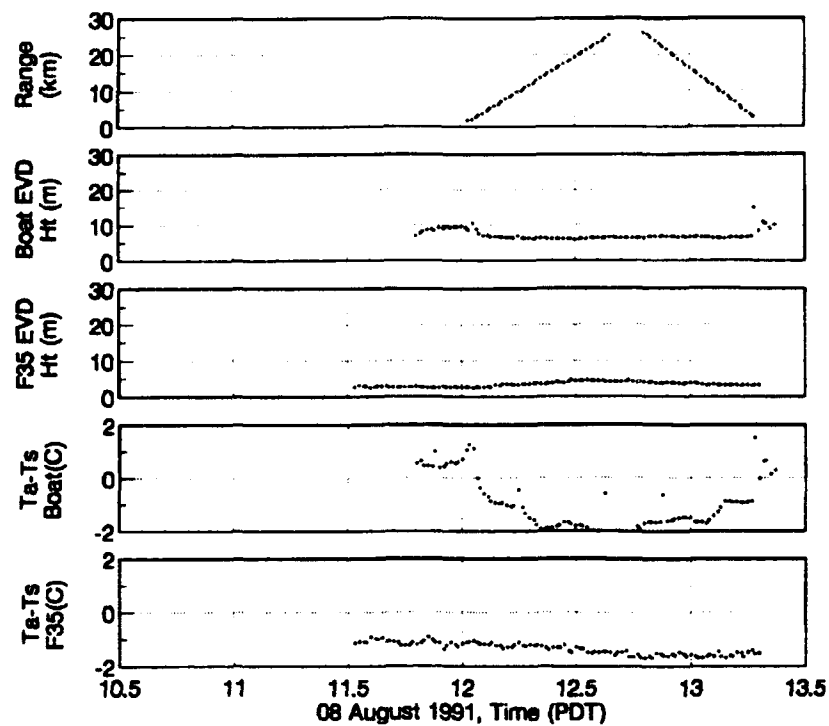


Figure 109. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 08/08/91.

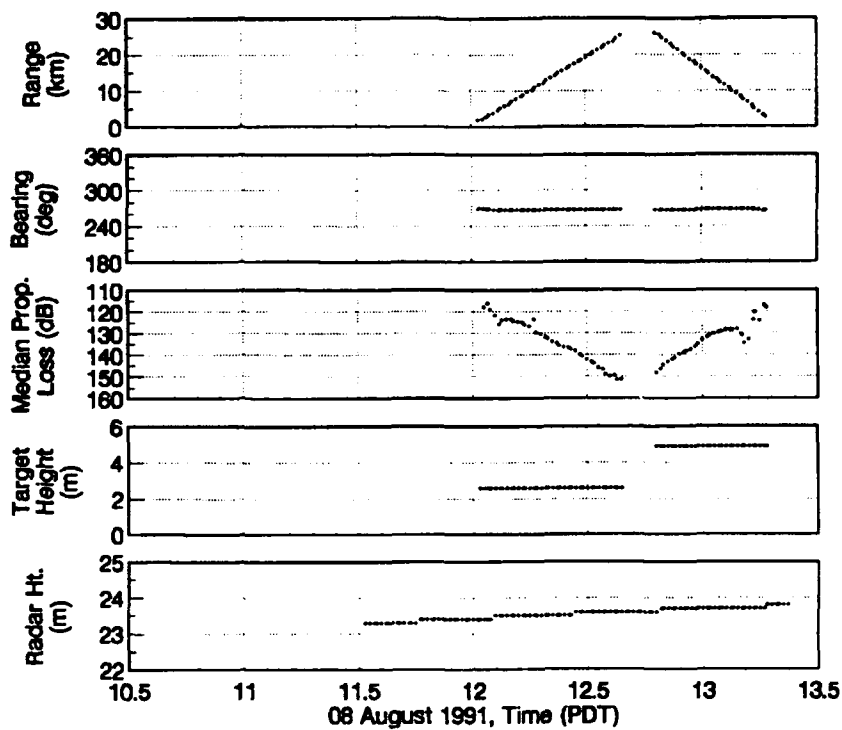


Figure 110. Target bearing from radar, median propagation loss, target and radar heights for 08/08/91.

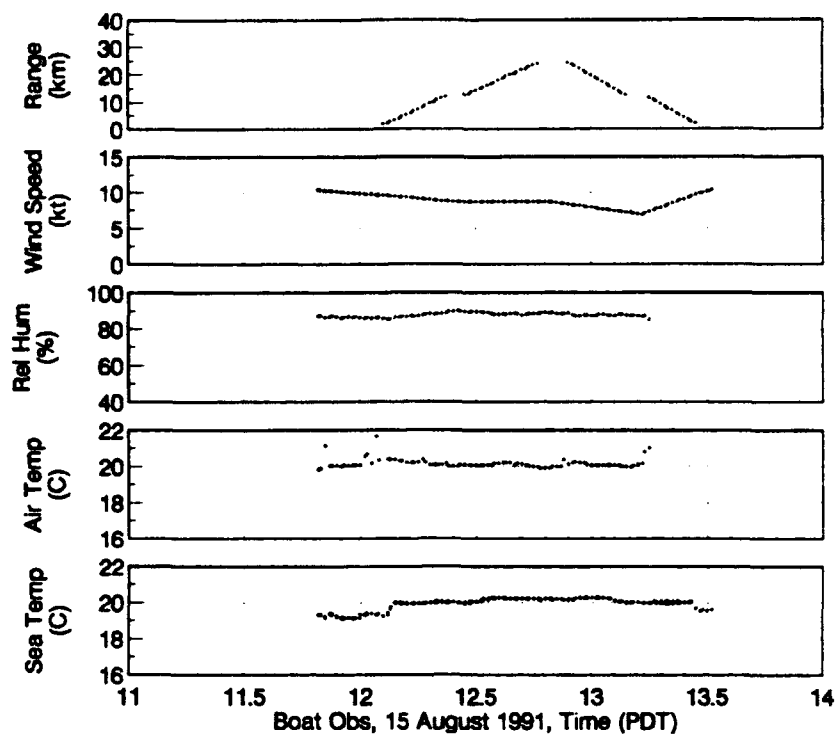


Figure 111. Surface meteorological observations as measured on the boat for 08/15/91.

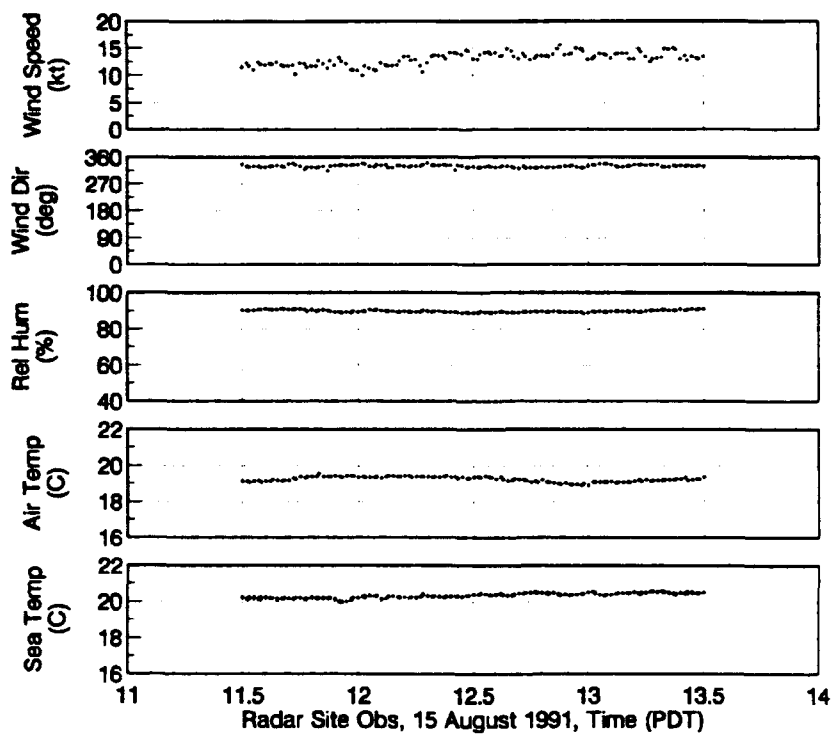


Figure 112. Surface meteorological observations as measured at the F35 site for 08/15/91.

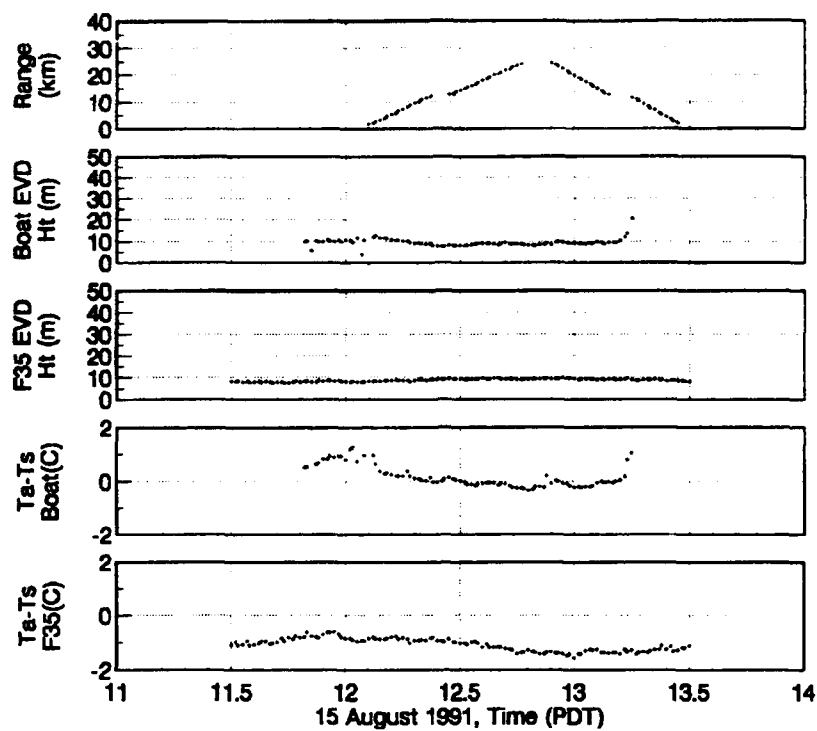


Figure 113. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 08/15/91.

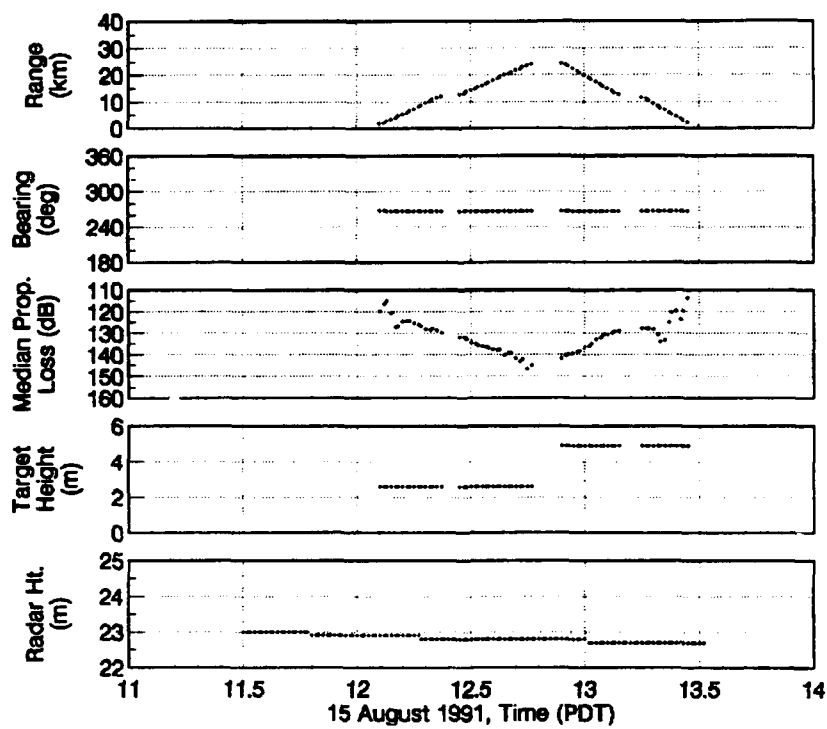


Figure 114. Target bearing from radar, median propagation loss, target and radar heights for 08/15/91.

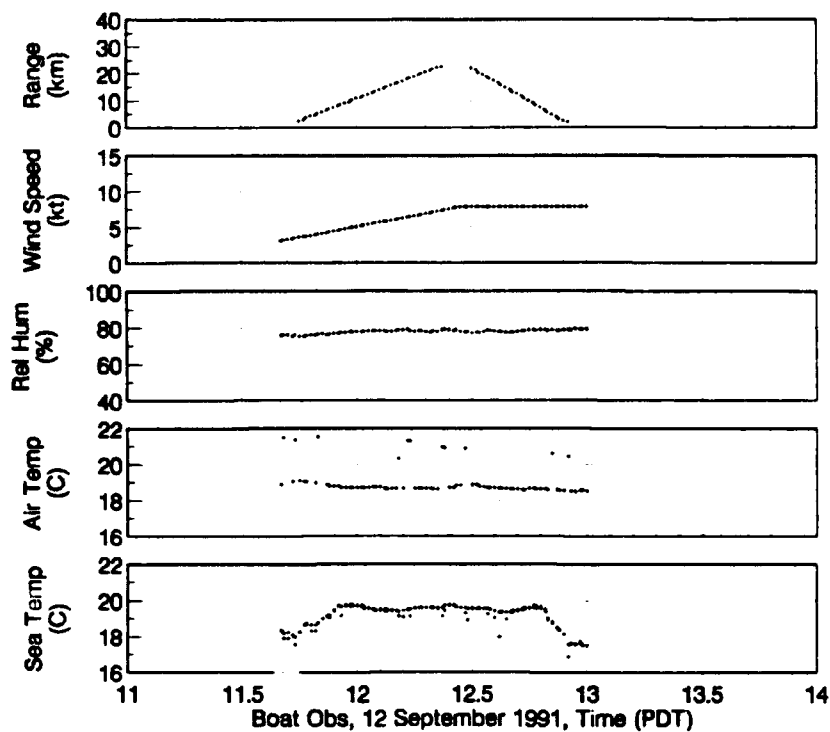


Figure 115. Surface meteorological observations as measured on the boat for 09/12/91.

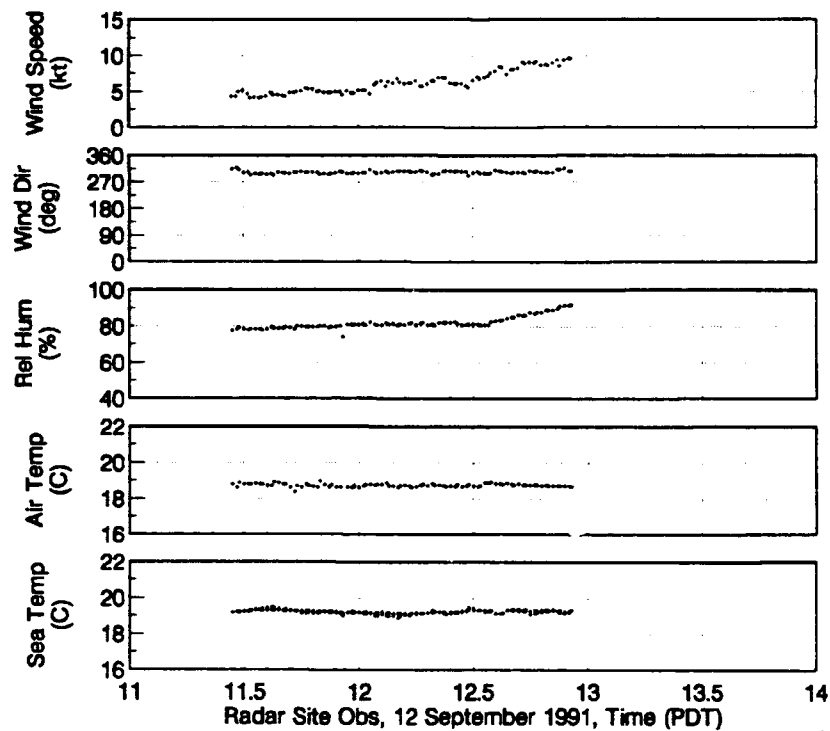


Figure 116. Surface meteorological observations as measured at the F35 site for 09/12/91.

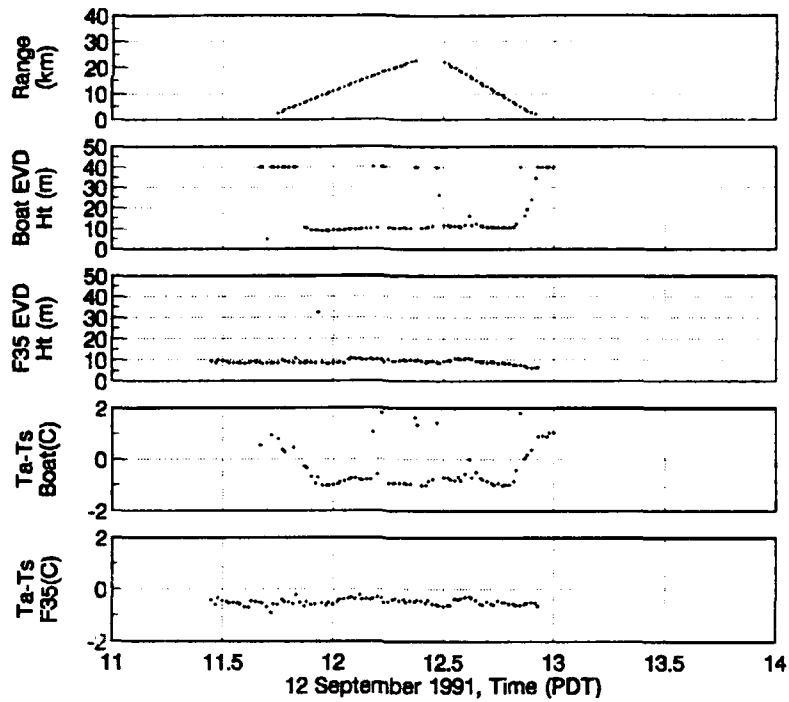


Figure 117. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 09/12/91.

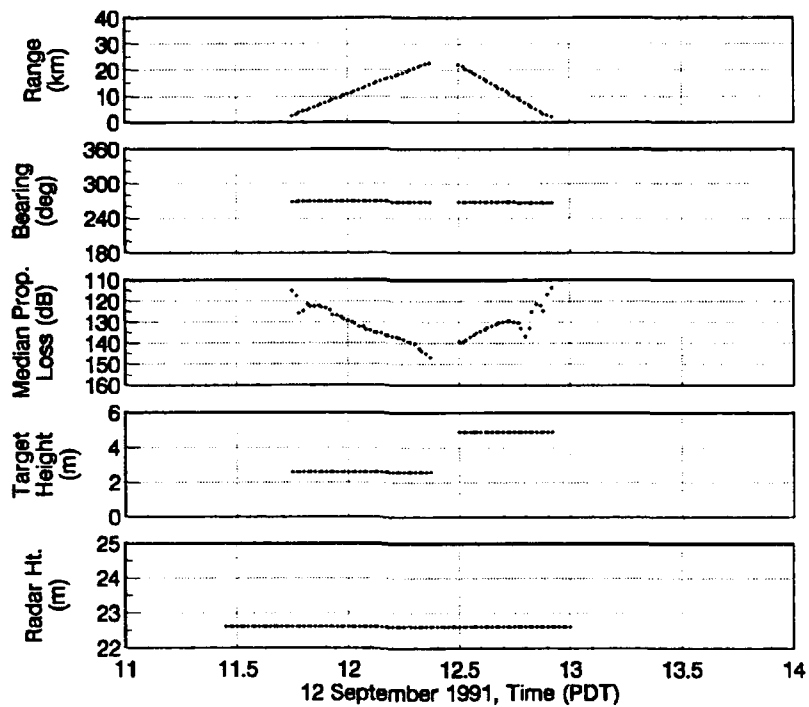


Figure 118. Target bearing from radar, median propagation loss, target and radar heights for 09/12/91.

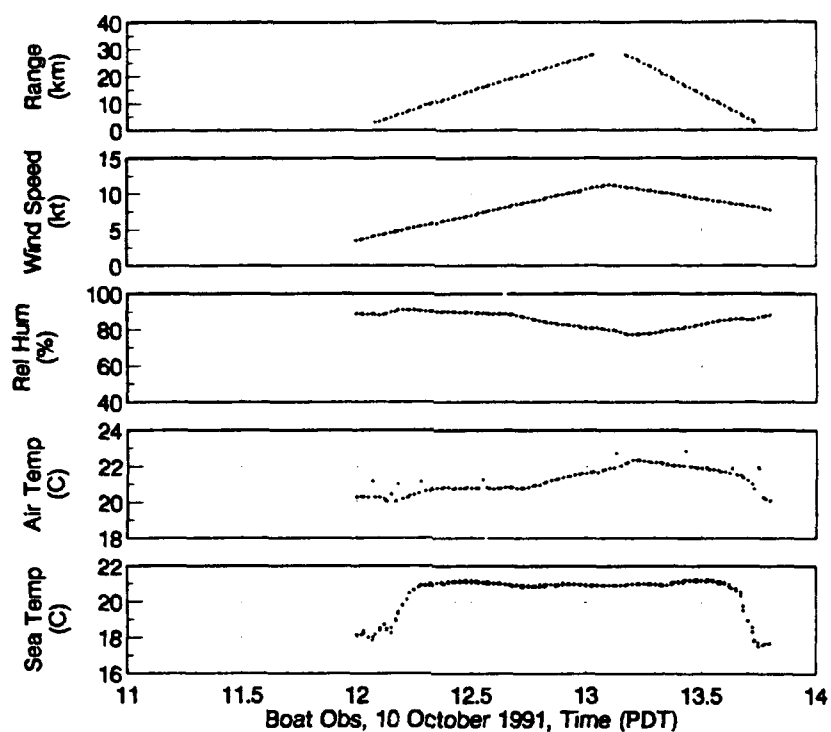


Figure 119. Surface meteorological observations as measured on the boat for 10/10/91.

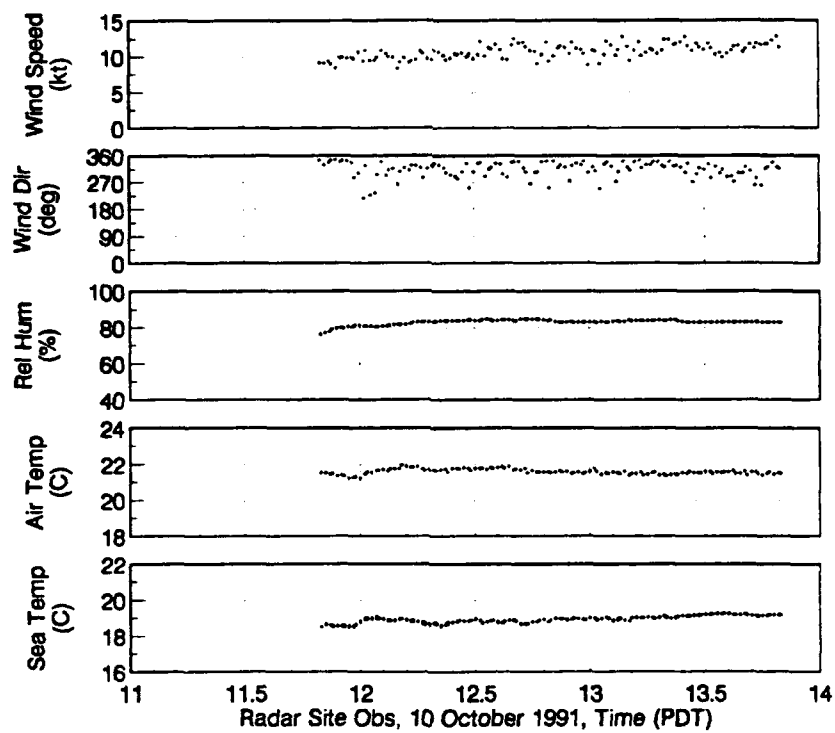


Figure 120. Surface meteorological observations as measured at the F35 site for 10/10/91.

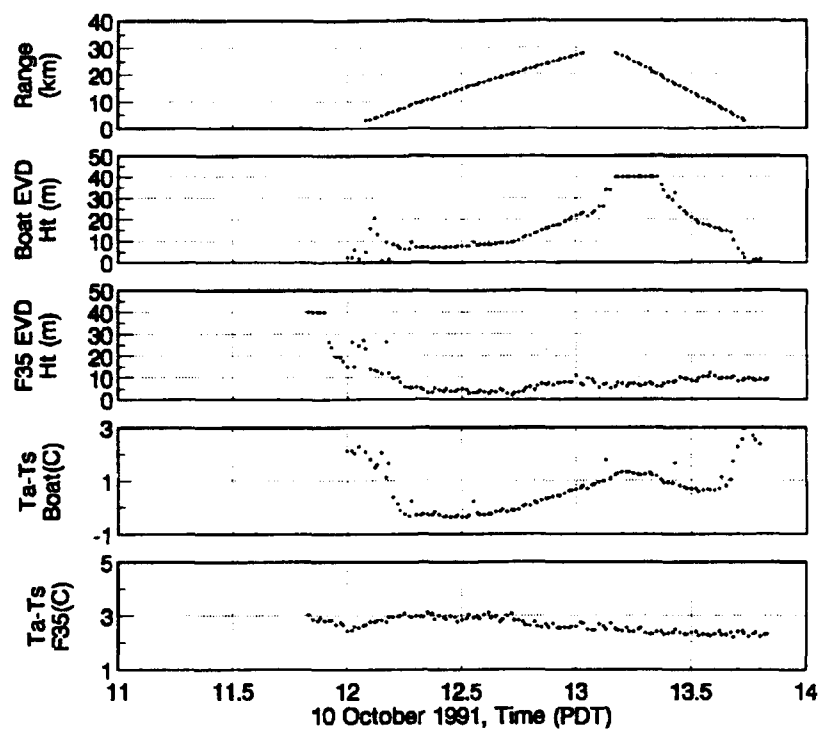


Figure 121. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 10/10/91.

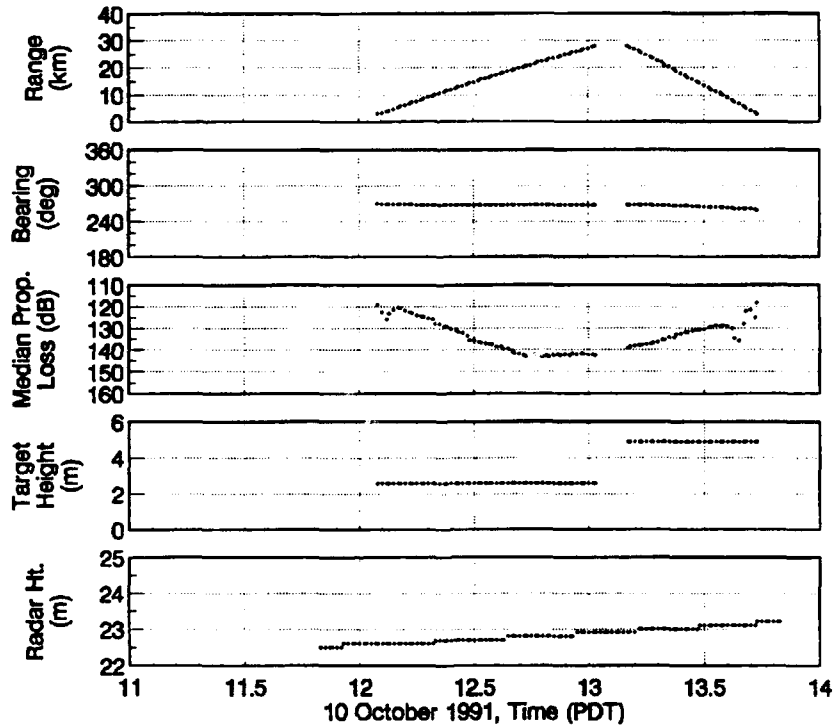


Figure 122. Target bearing from radar, median propagation loss, target and radar heights for 10/10/91.

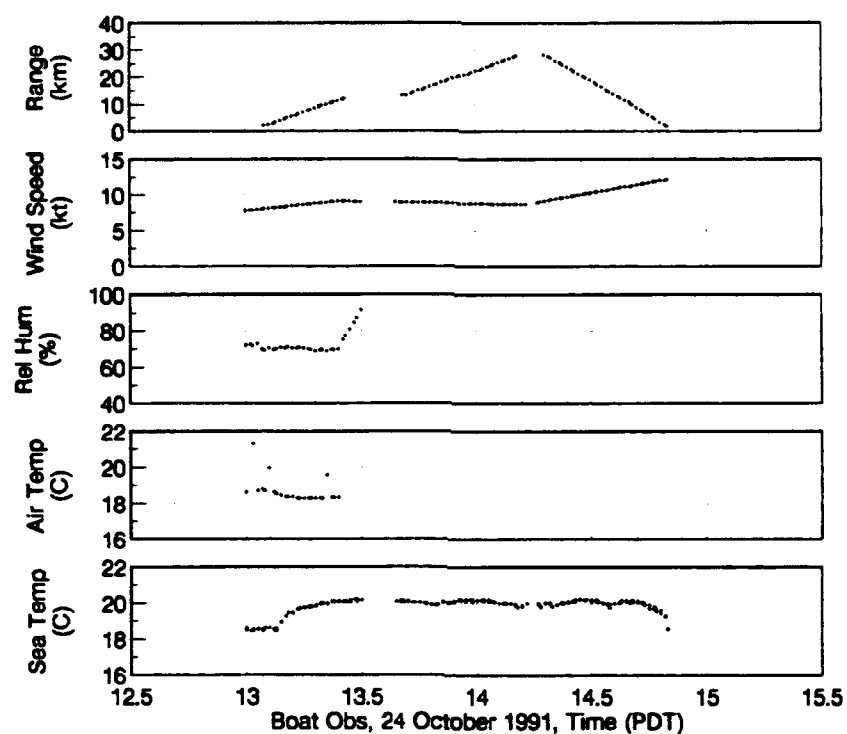


Figure 123. Surface meteorological observations as measured on the boat for 10/24/91.

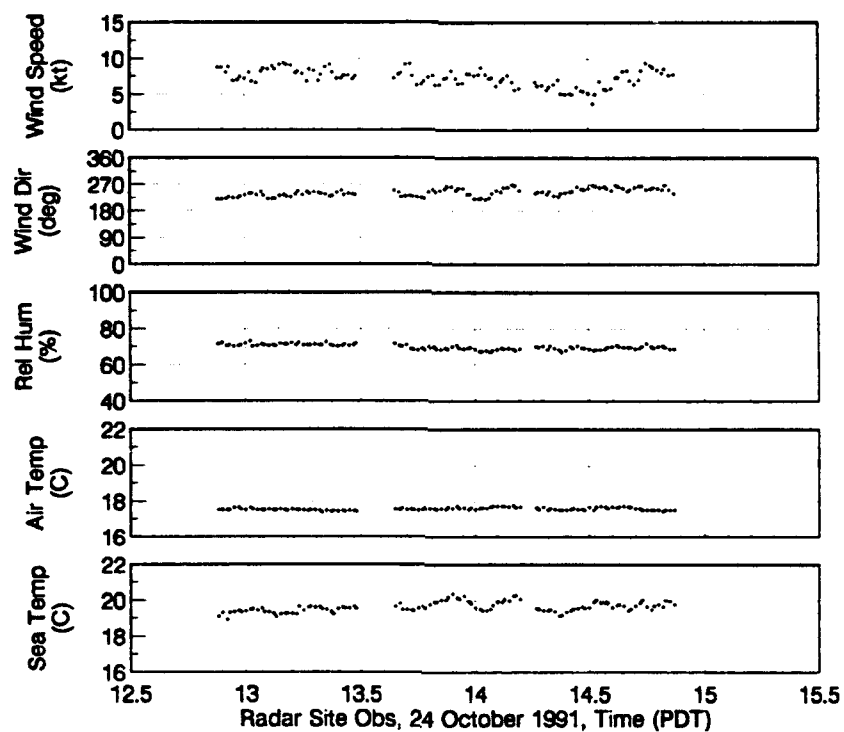


Figure 124. Surface meteorological observations as measured at the F35 site for 10/24/91.

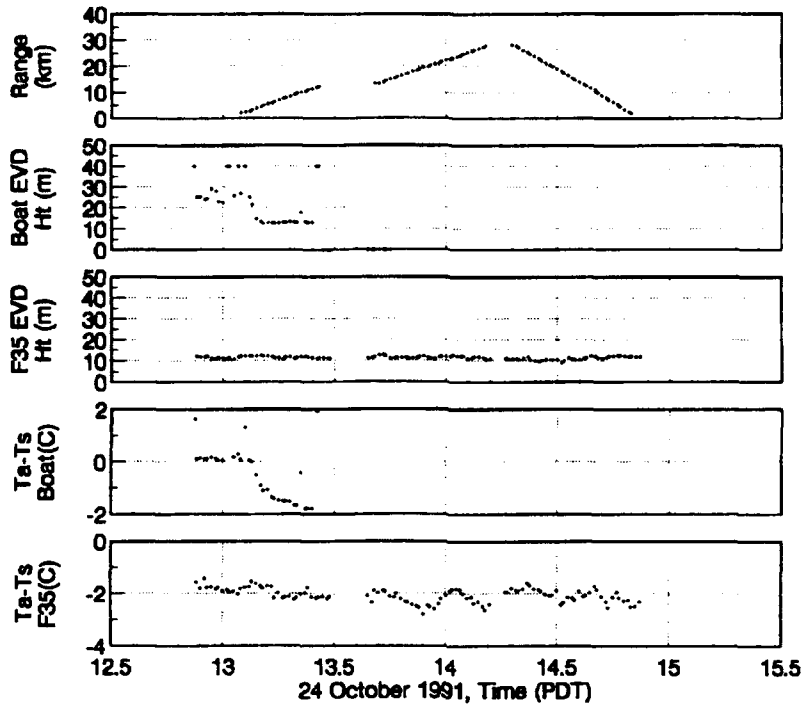


Figure 125. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 10/24/91.

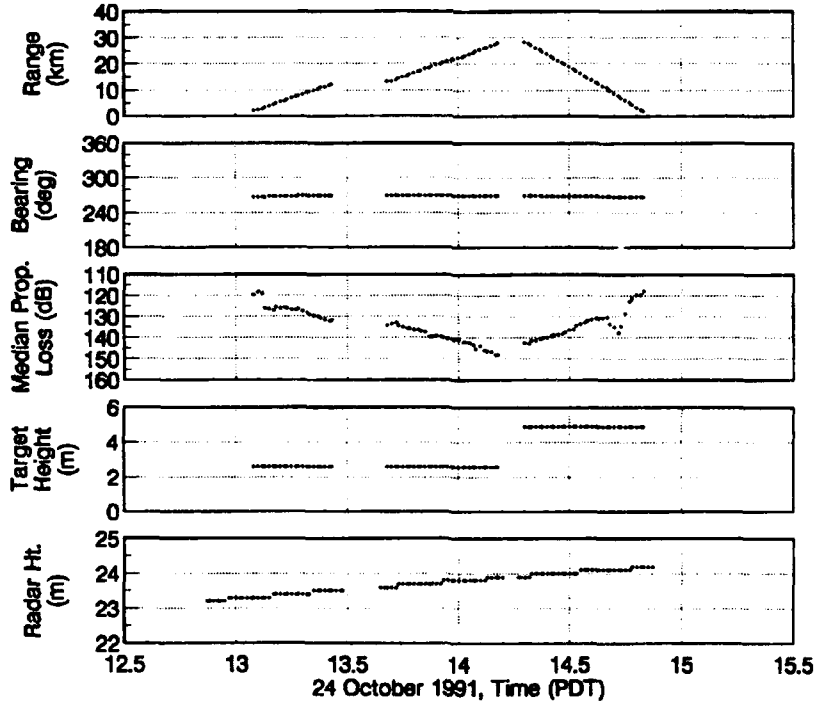


Figure 126. Target bearing from radar, median propagation loss, target and radar heights for 10/24/91.

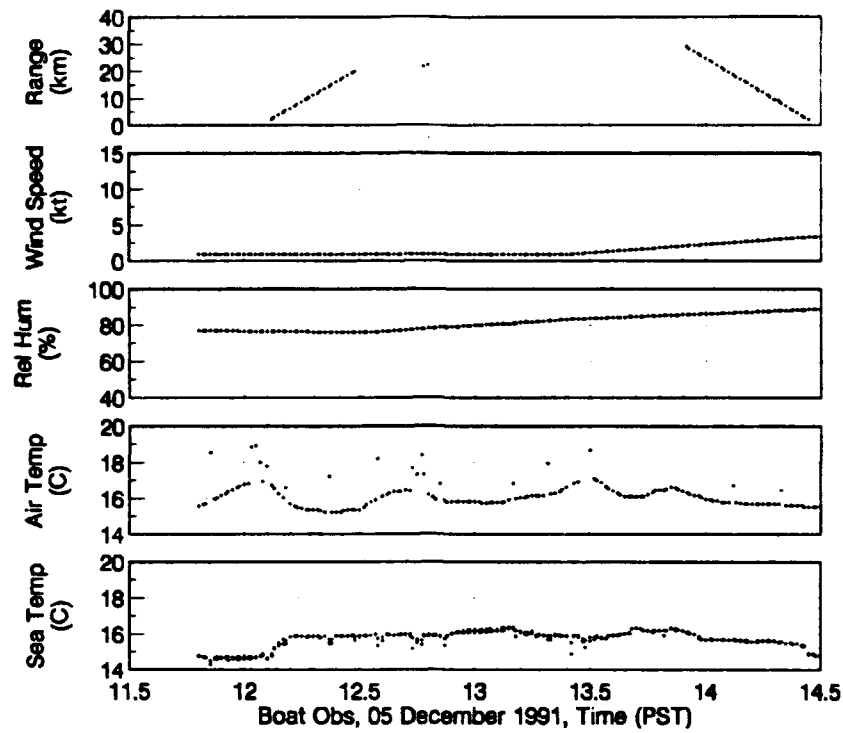


Figure 127. Surface meteorological observations as measured on the boat for 12/05/91.

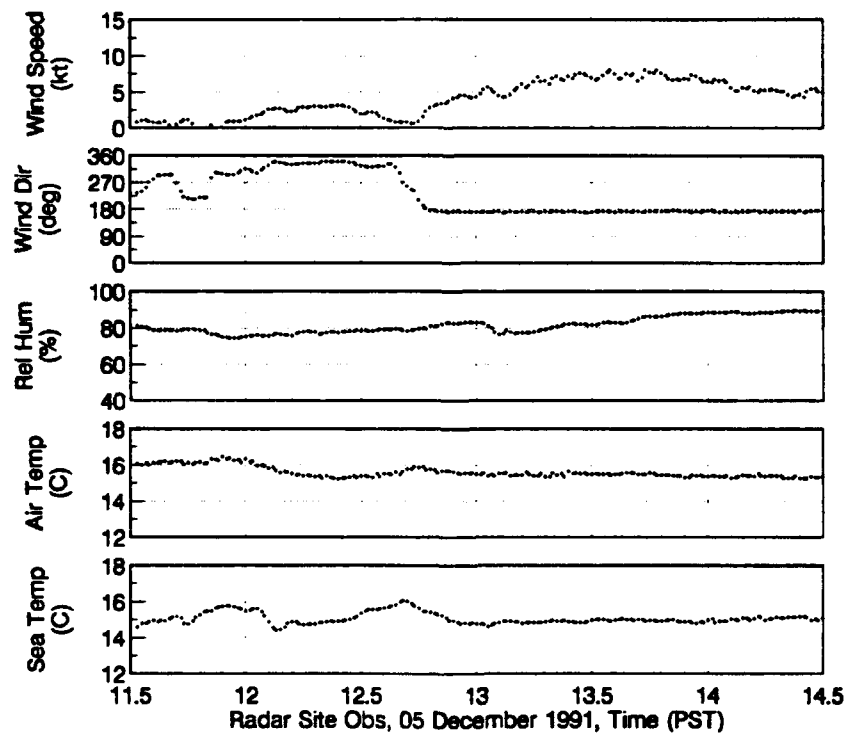


Figure 128. Surface meteorological observations as measured at the F35 site for 12/05/91.

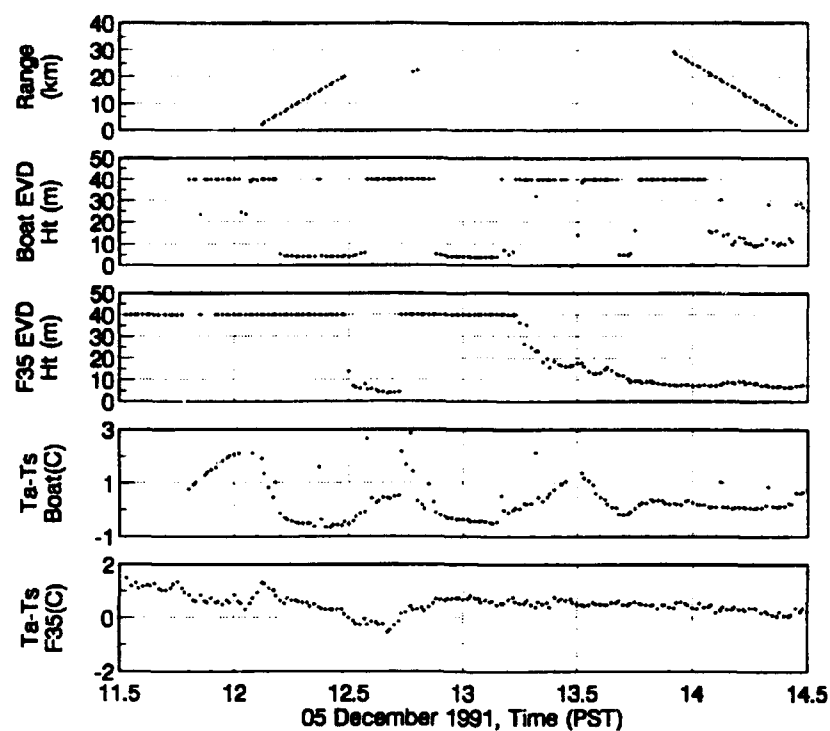


Figure 129. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 12/05/91.

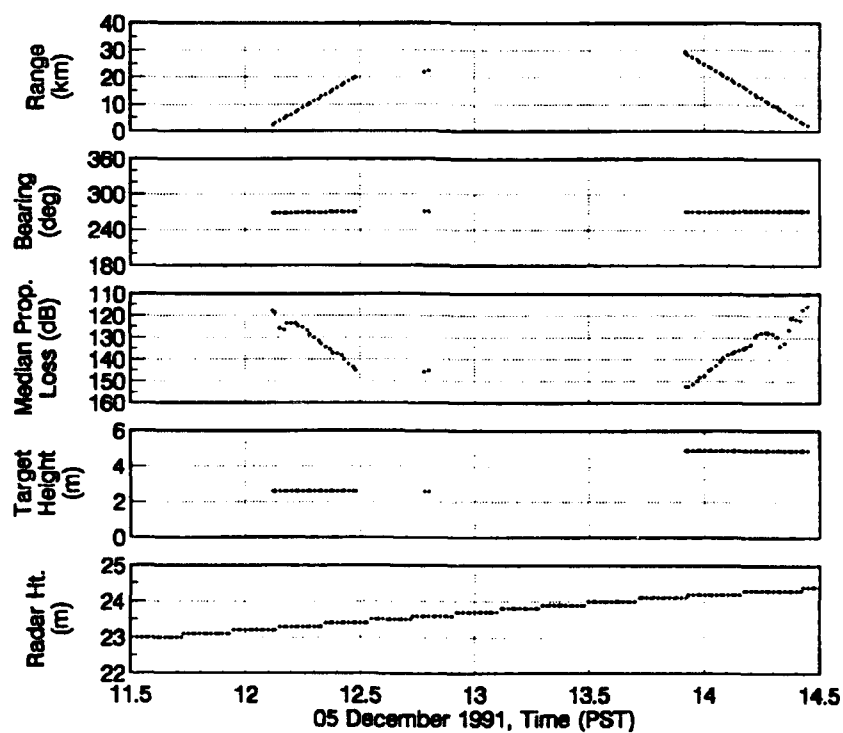


Figure 130. Target bearing from radar, median propagation loss, target and radar heights for 12/05/91.

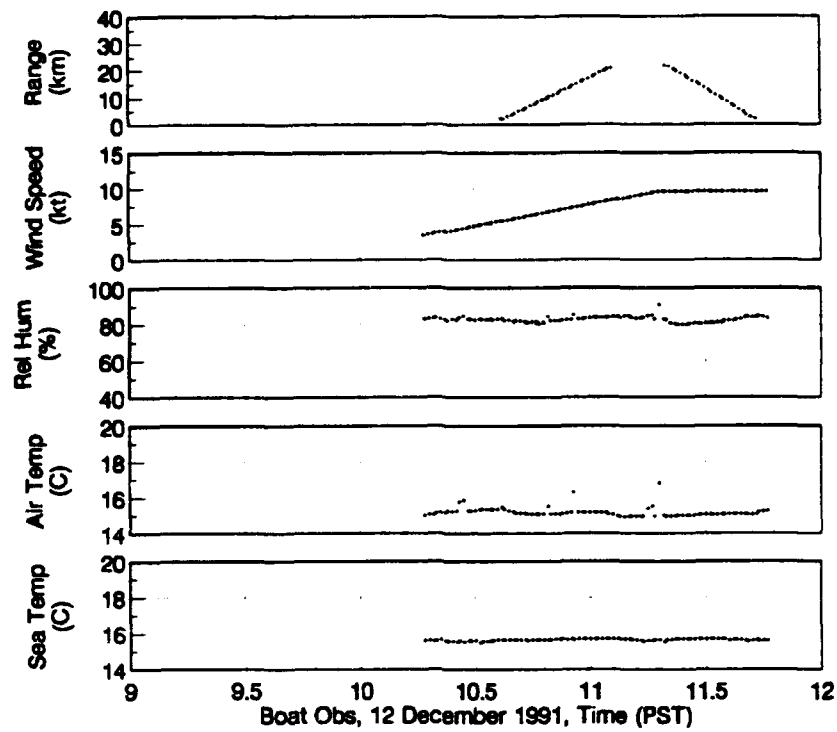


Figure 131. Surface meteorological observations as measured on the boat for 12/12/91.

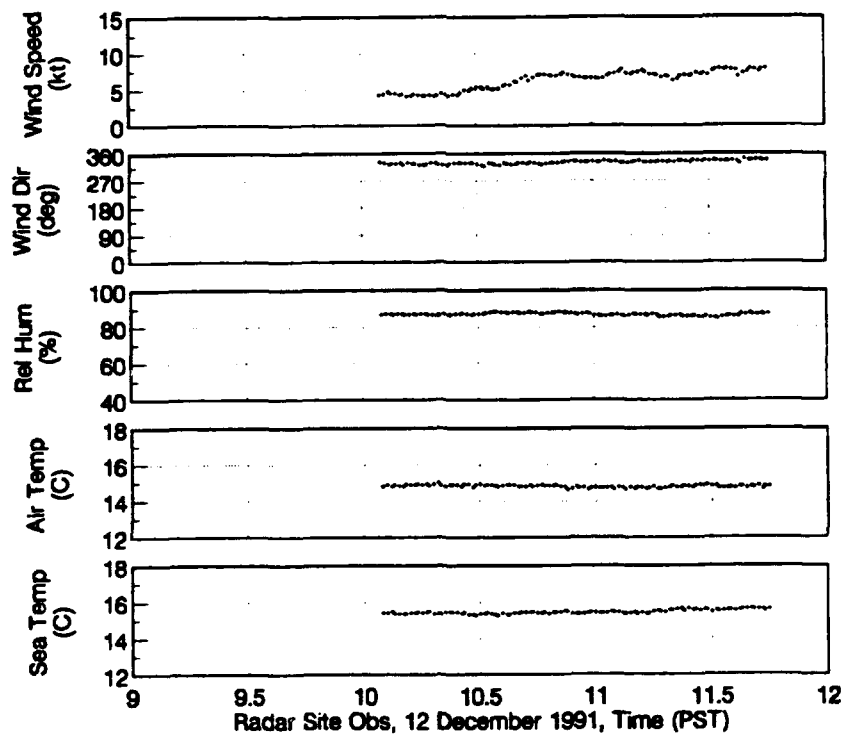


Figure 132. Surface meteorological observations as measured at the F35 site for 12/12/91.

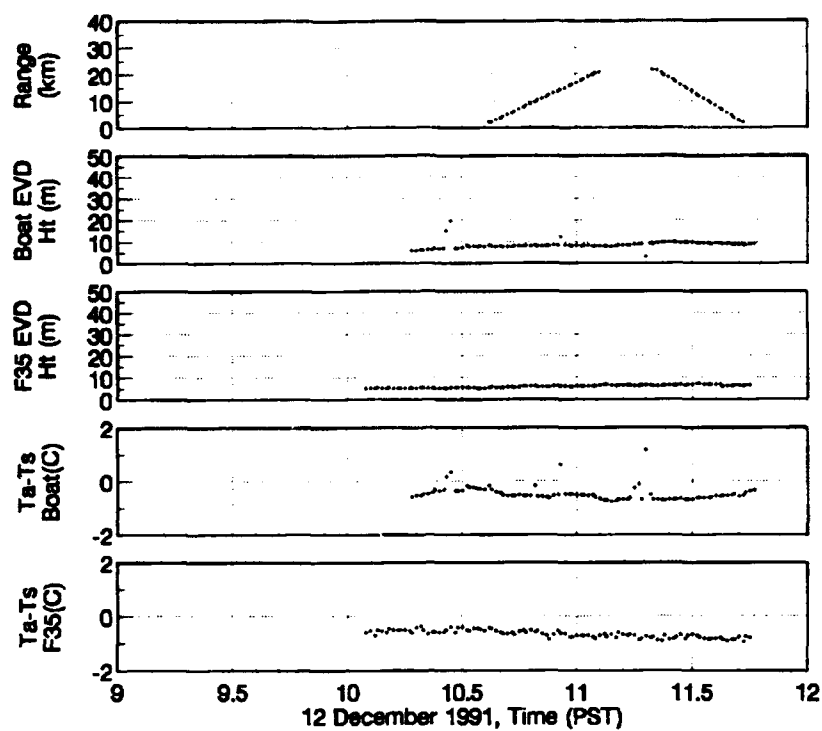


Figure 133. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 12/12/91.

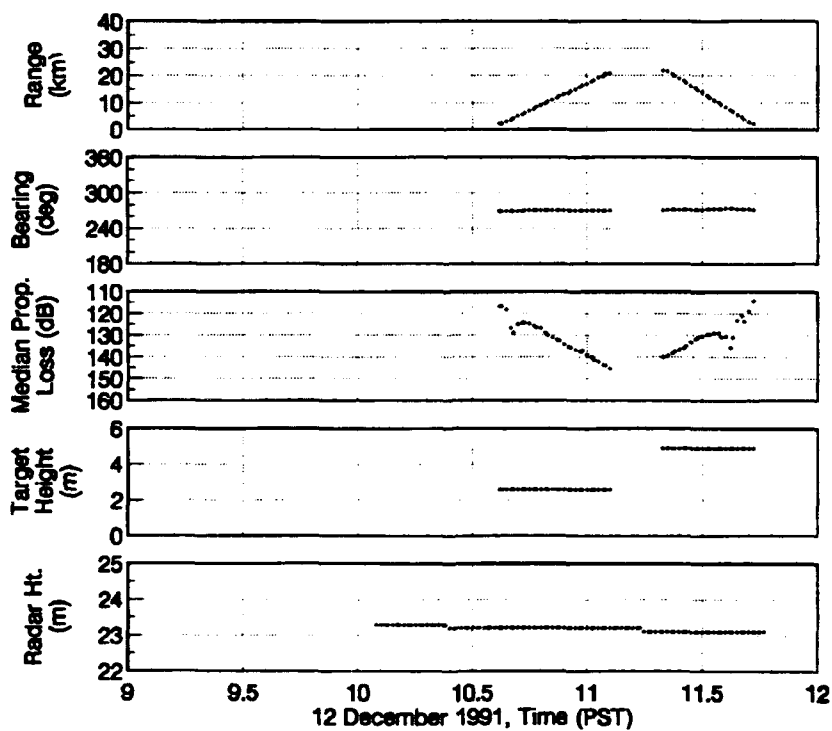


Figure 134. Target bearing from radar, median propagation loss, target and radar heights for 12/12/91.

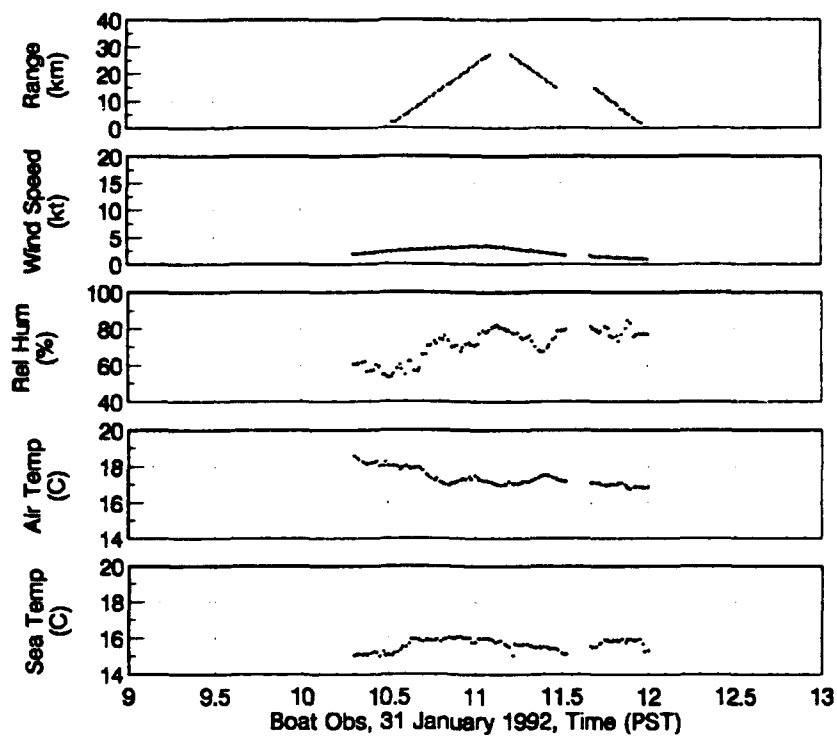


Figure 135. Surface meteorological observations as measured on the boat for 01/31/92.

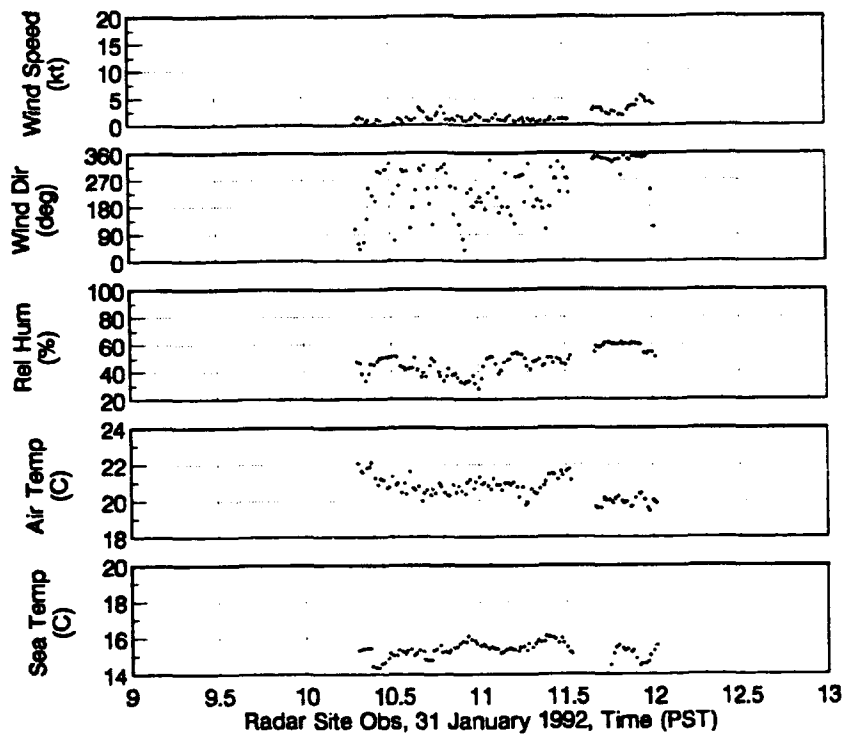


Figure 136. Surface meteorological observations as measured at the F35 site for 01/31/92.

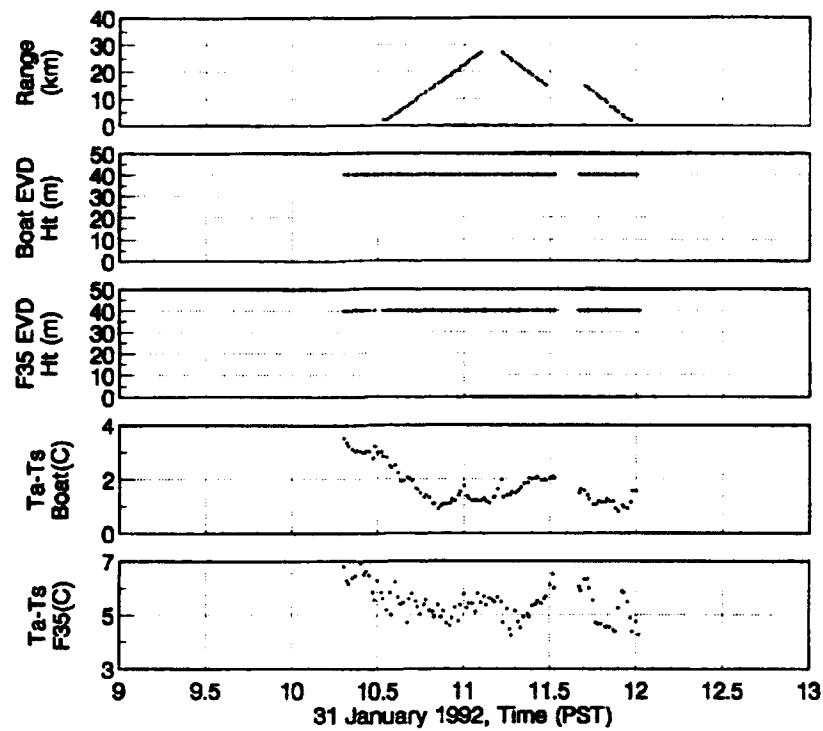


Figure 137. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 01/31/92.

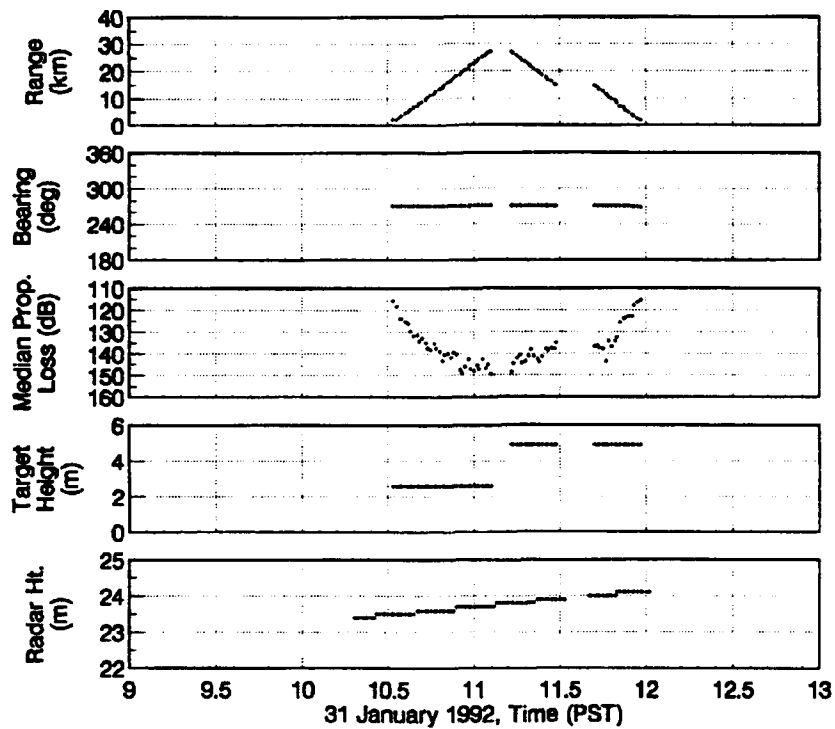


Figure 138. Target bearing from radar, median propagation loss, target and radar heights for 01/31/92.

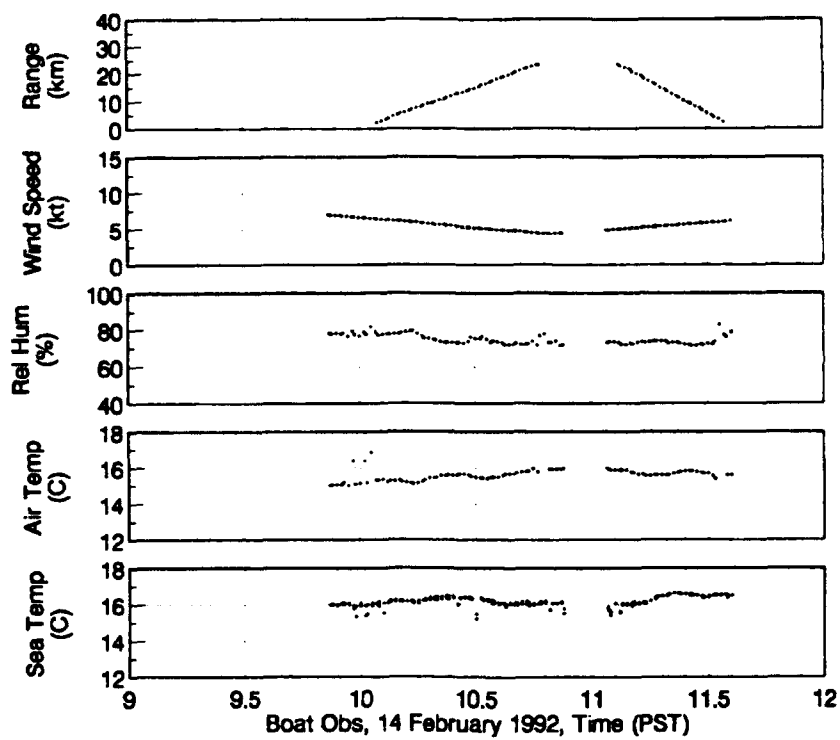


Figure 139. Surface meteorological observations as measured on the boat for 02/14/92.

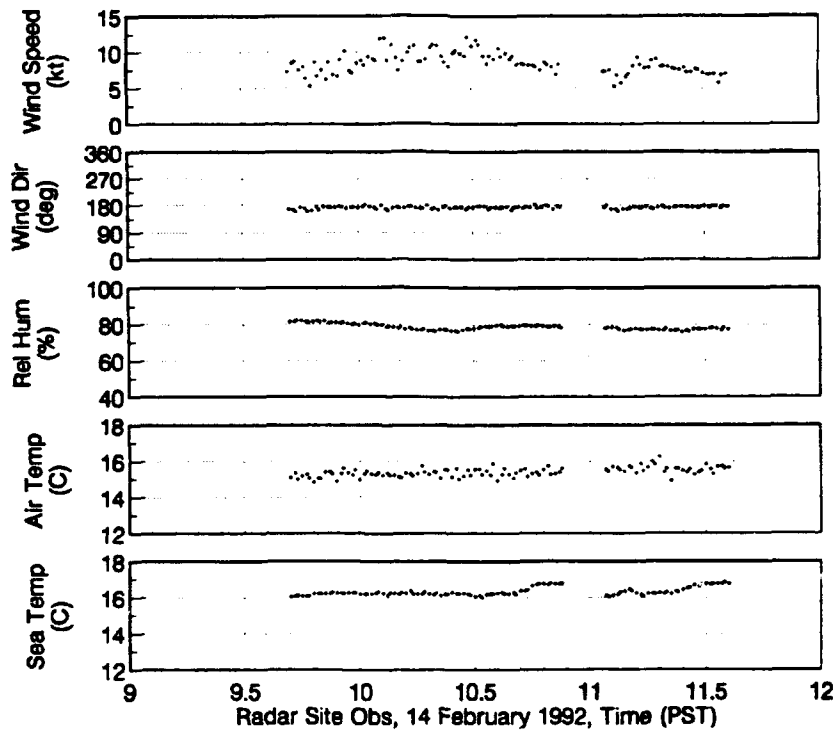


Figure 140. Surface meteorological observations as measured at the F35 site for 02/14/92.

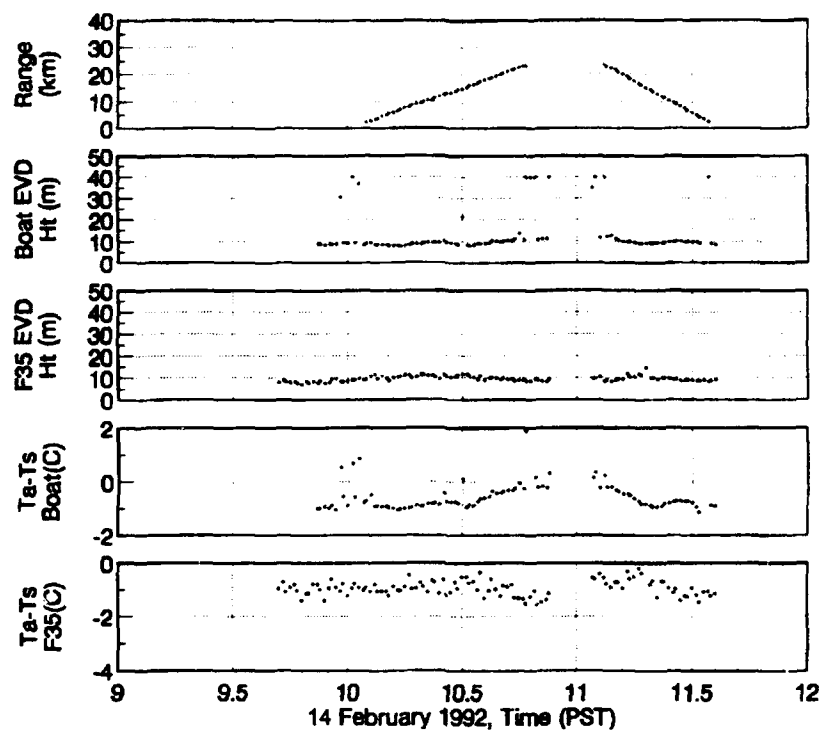


Figure 141. Evaporation duct heights and air-sea temperature differences as measured on the boat and at the F35 site for 02/14/92.

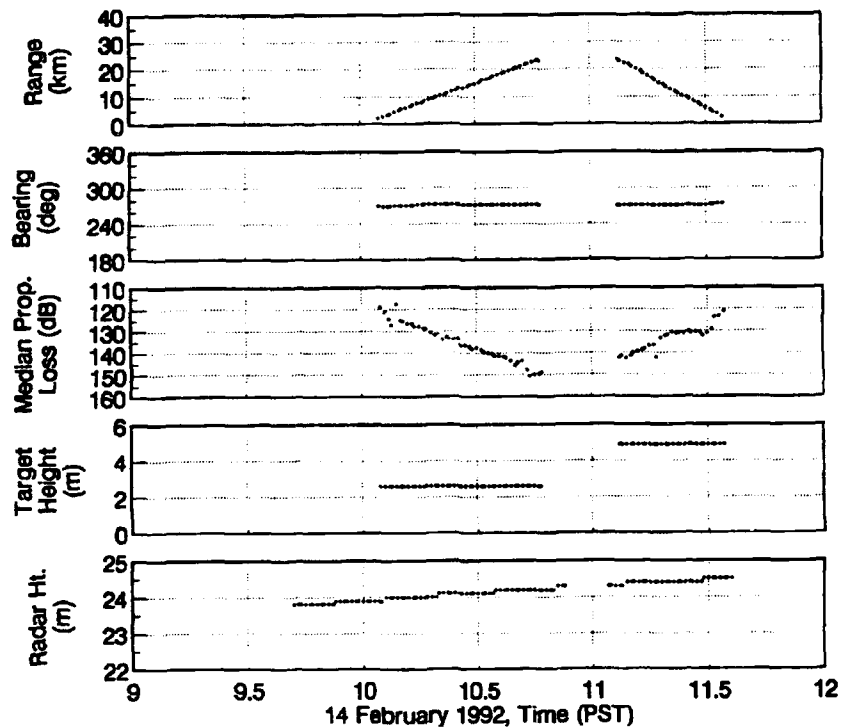


Figure 142. Target bearing from radar, median propagation loss, target and radar heights for 02/14/92.

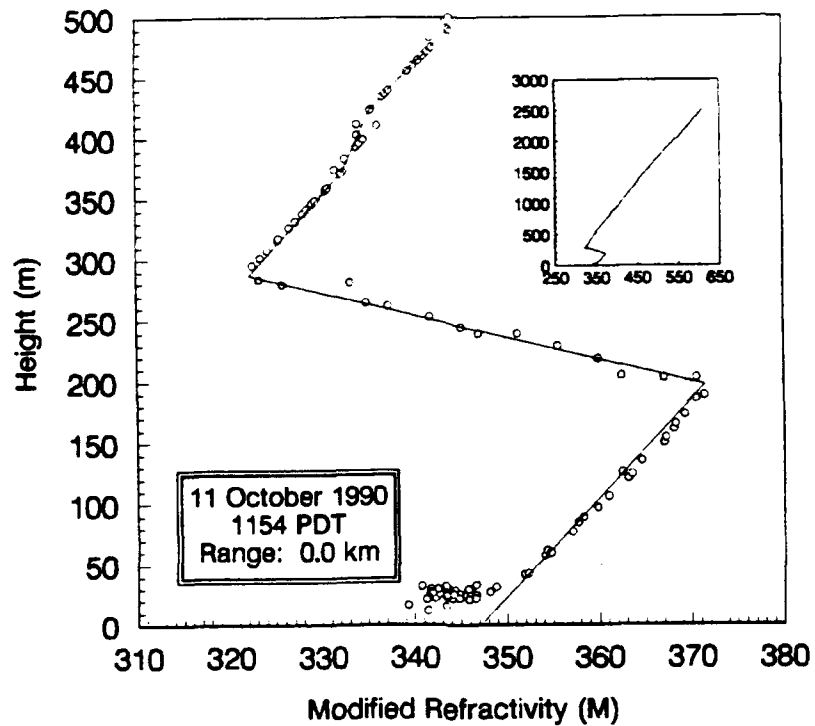


Figure 143. Modified refractivity versus height for the radiosonde on 10/11/1990 at 11:54 PDT.

Radar Site
Launch Height: 22 m

Height (m)	M-Units
0.00	347.18
197.13	371.54
286.74	322.22
372.76	332.44
422.94	335.45
523.30	348.08
562.72	349.59
100.00	407.33

Figure 144. List of modified refractivity versus height for the radiosonde on 10/11/1990 at 11:54 PDT.

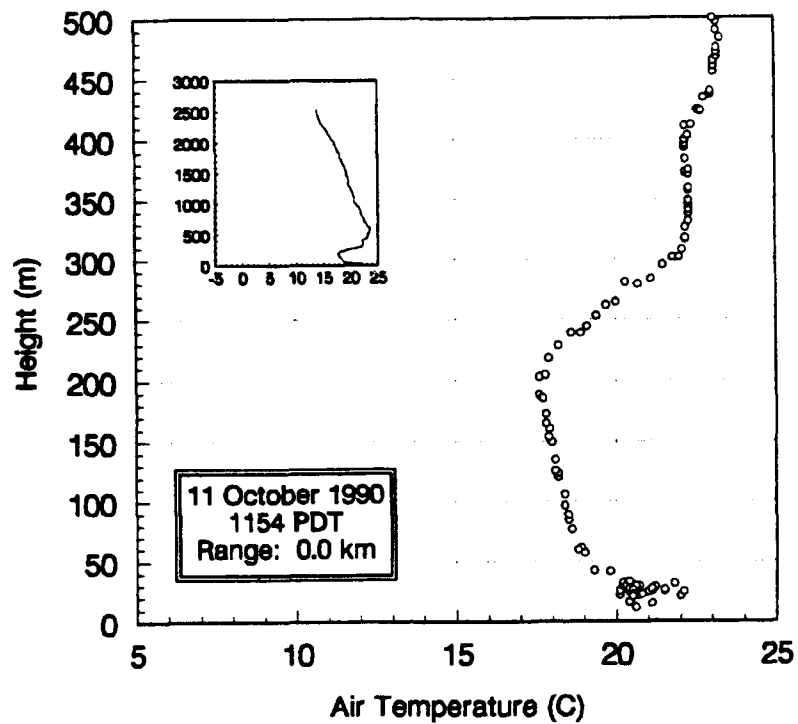


Figure 145. Relative humidity versus height for the radiosonde on 10/11/1990 at 11:54 PDT.

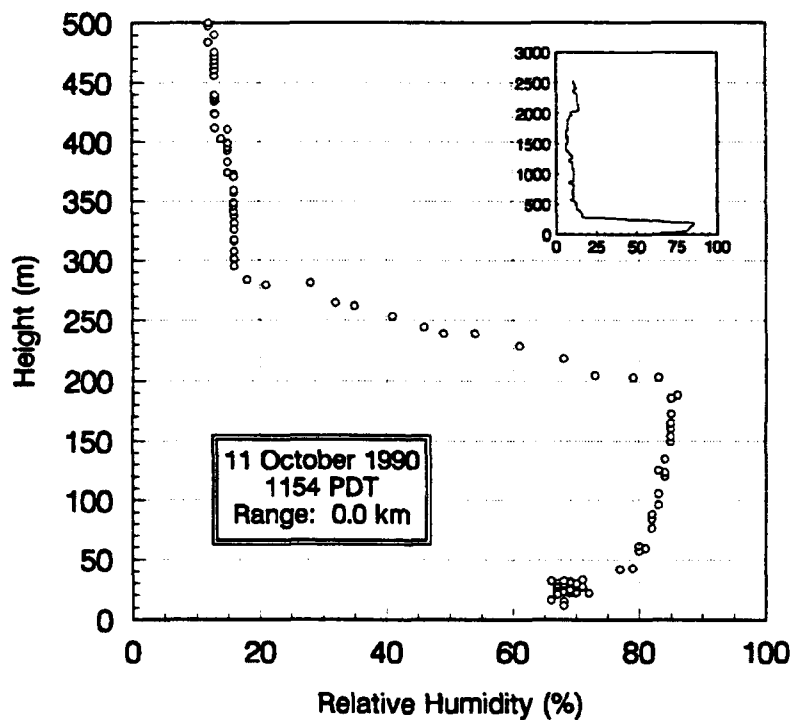


Figure 146. Air temperature versus height for the radiosonde on 10/11/1990 at 11:54 PDT.

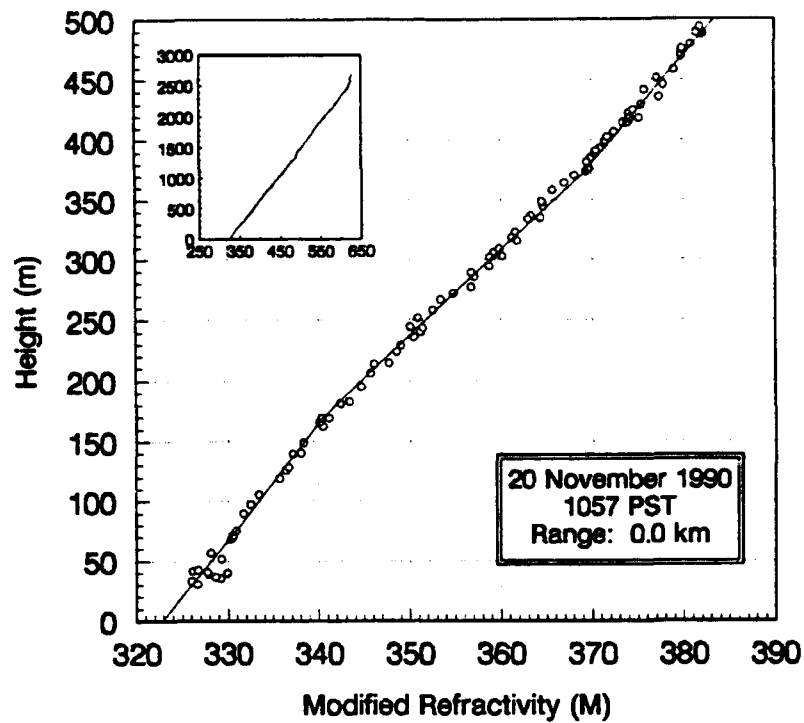


Figure 147. Modified refractivity versus height for the radiosonde on 12/20/1990 at 10:57 PST.

Radar Site	
Launch Height: 33 m	
Height (m)	M- Units
0.00	322.82
78.85	331.24
168.46	340.26
372.76	369.14
652.33	400.41
928.32	435.00

Figure 148. List of modified refractivity versus height for the radiosonde on 11/20/1990 at 10:57 PST.

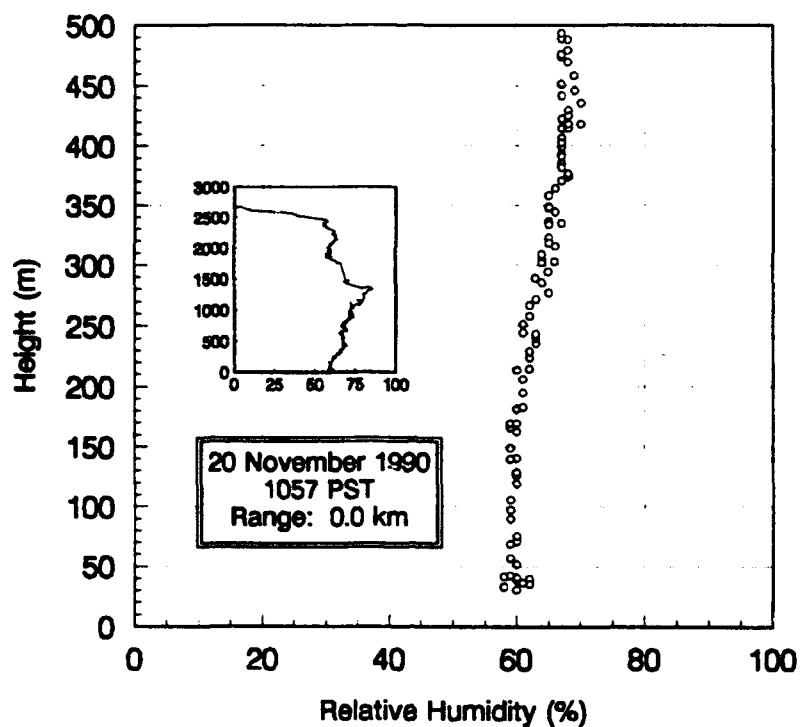


Figure 149. Relative humidity versus height for the radiosonde on 12/20/1990 at 10:57 PST.

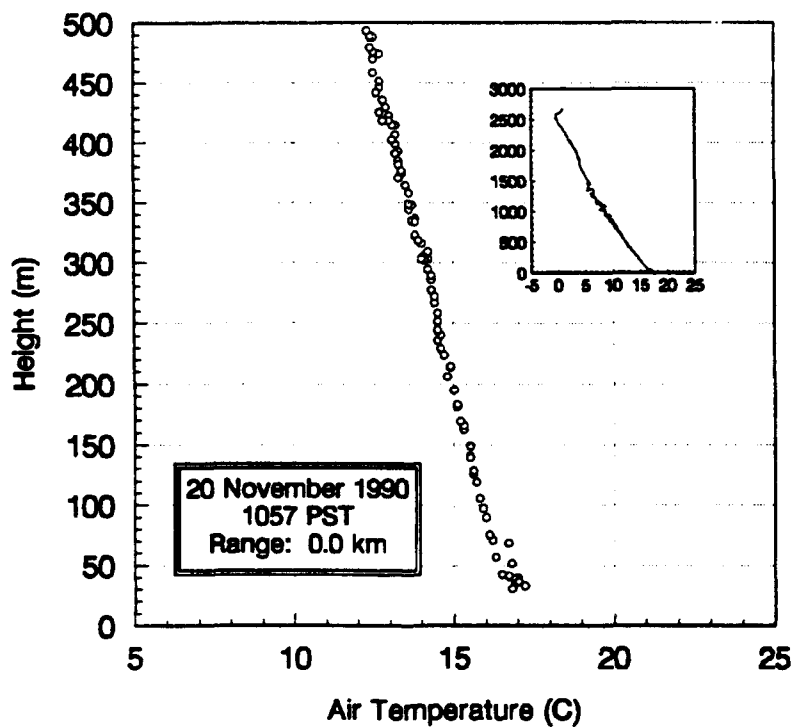


Figure 150. Air temperature versus height for the radiosonde on 12/20/1990 at 10:57 PST.

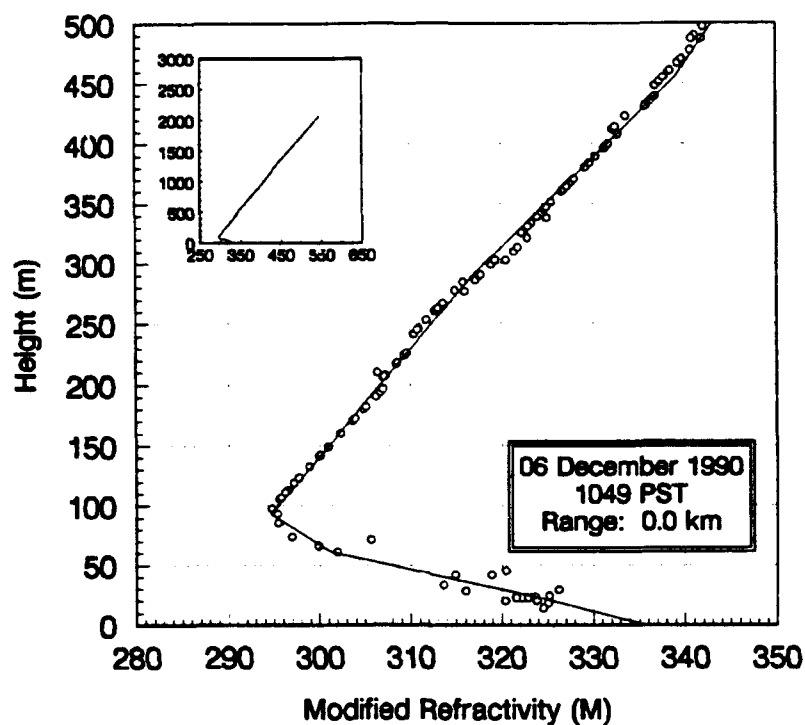


Figure 151. Modified refractivity versus height for the radiosonde on 12/06/1990 at 10:49 PST.

Radar Site
Launch Height: 20 m

Height (m)	M-Units
0.00	335.83
21.51	324.70
60.93	301.24
93.19	294.62
290.32	316.88
455.20	339.14
544.80	346.95
978.49	405.00

Figure 152. List of modified refractivity versus height for the radiosonde on 12/06/1990 at 10:49 PST.

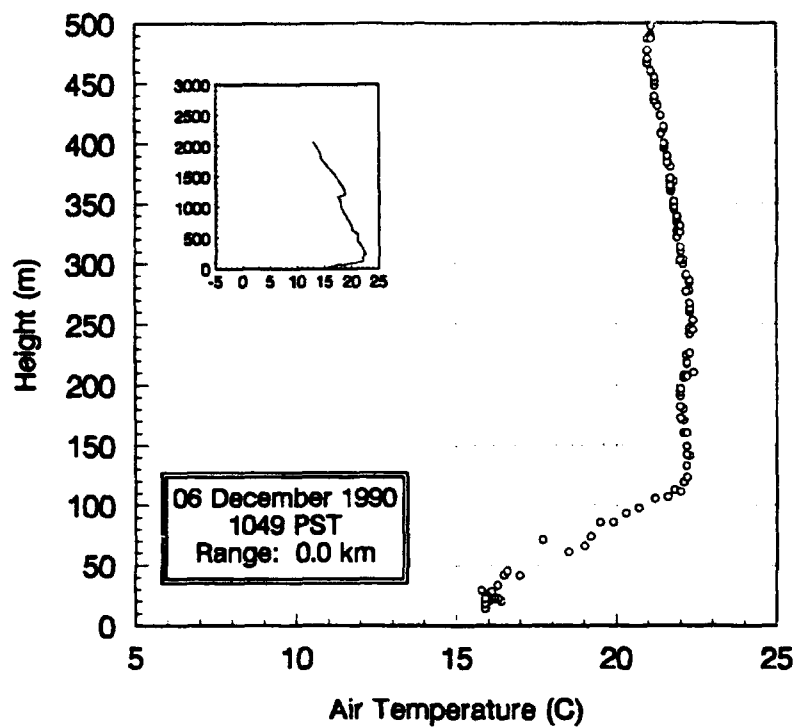


Figure 153. Relative humidity versus height for the radiosonde on 12/06/1990 at 10:49 PST.

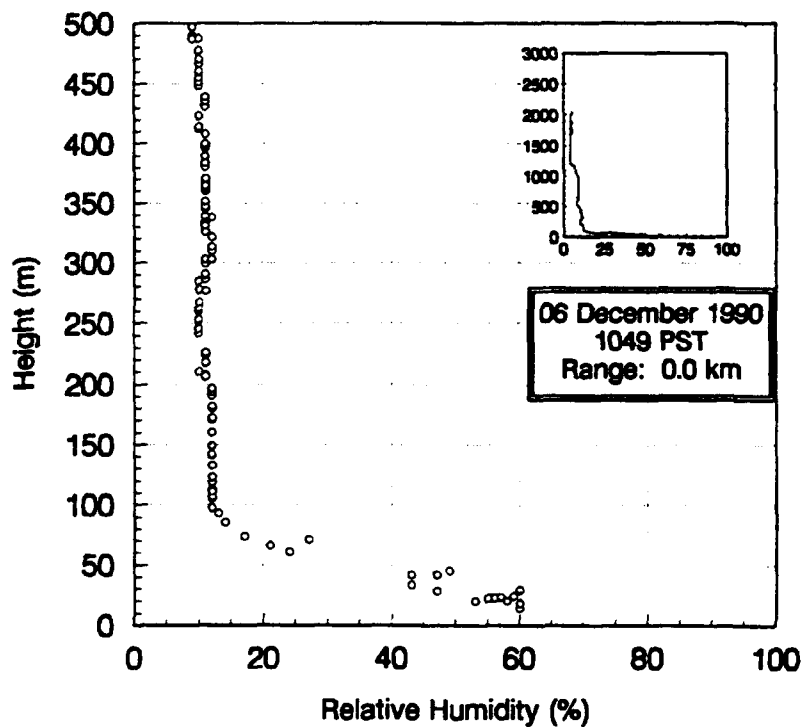


Figure 154. Air temperature versus height for the radiosonde on 12/06/1990 at 10:49 PST.

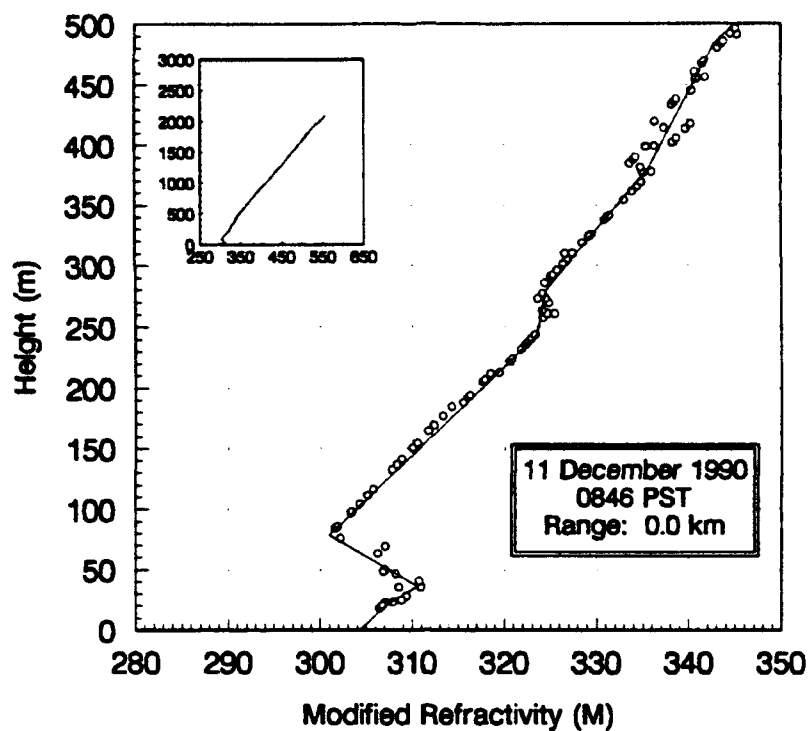


Figure 155. Modified refractivity versus height for the radiosonde on 12/11/1990 at 08:46 PST.

Radar Site
Launch Height: 23 m

Height (m)	M-Units
0.00	304.32
21.51	307.33
35.84	310.64
78.85	301.02
243.73	323.57
279.57	324.47
379.93	335.60
483.87	342.82
1000.00	410.49

Figure 156. List of modified refractivity versus height for the radiosonde on 12/11/1990 at 08:46 PST.

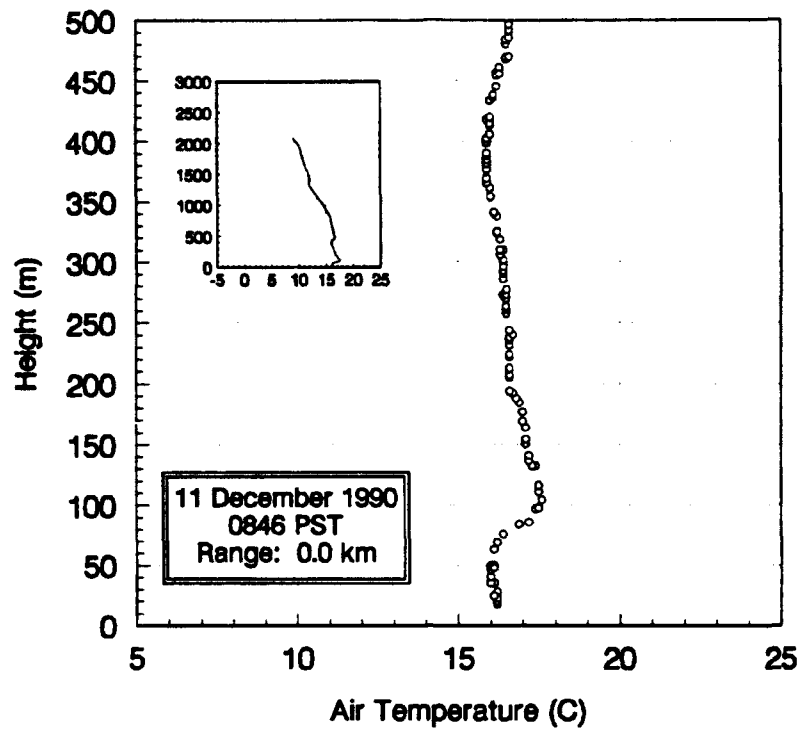


Figure 157. Relative humidity versus height for the radiosonde on 12/11/1990 at 08:46 PST.

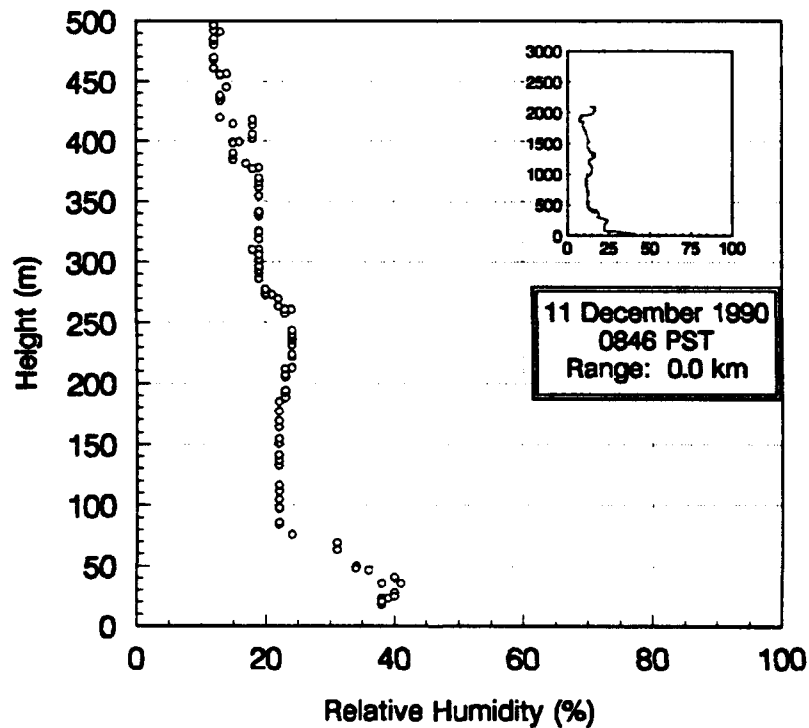


Figure 158. Air temperature versus height for the radiosonde on 12/11/1990 at 08:46 PST.

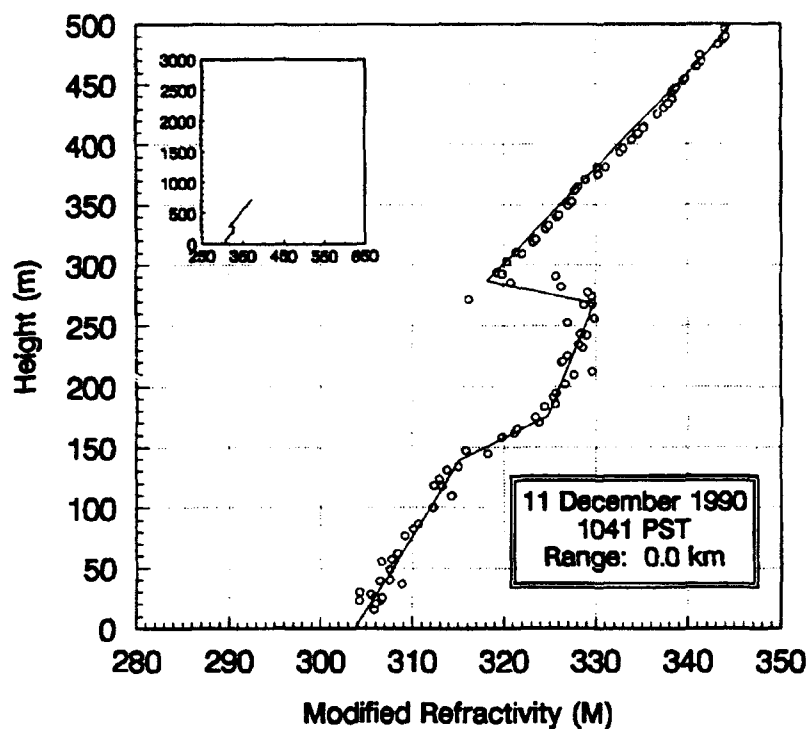


Figure 159. Modified refractivity versus height for the radiosonde on 12/11/1990 at 10:41 PST.

Radar Site
Launch Height: 23 m

Height (m)	M-Units
0.00	303.72
25.09	305.83
139.78	315.15
175.63	324.77
268.82	329.89
286.74	318.16
476.70	342.22
551.97	350.04
731.18	374.10

Figure 160. List of modified refractivity versus height for the radiosonde on 12/11/1990 at 10:41 PST.

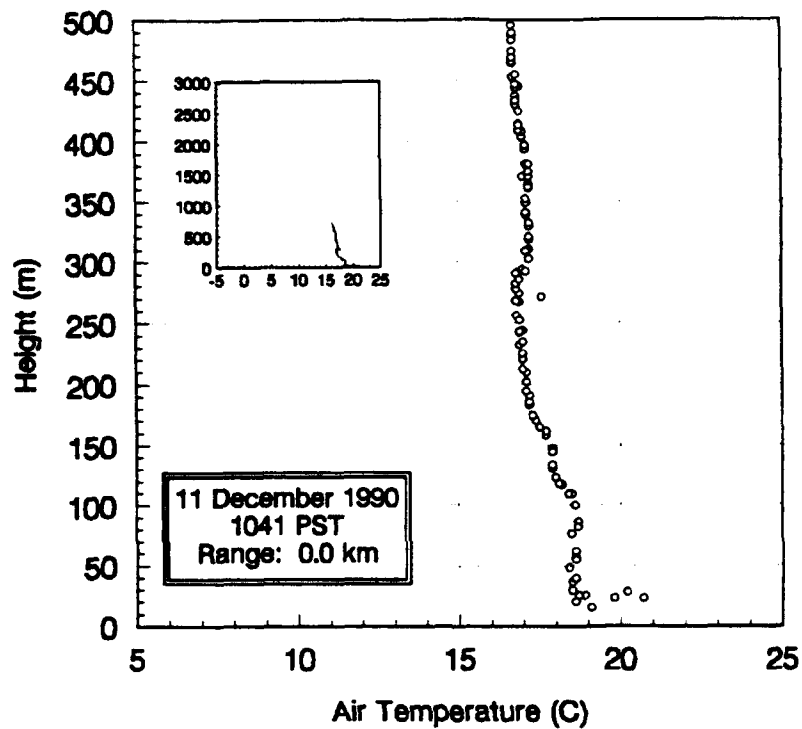


Figure 161. Relative humidity versus height for the radiosonde on 12/11/1990 at 10:41 PST.

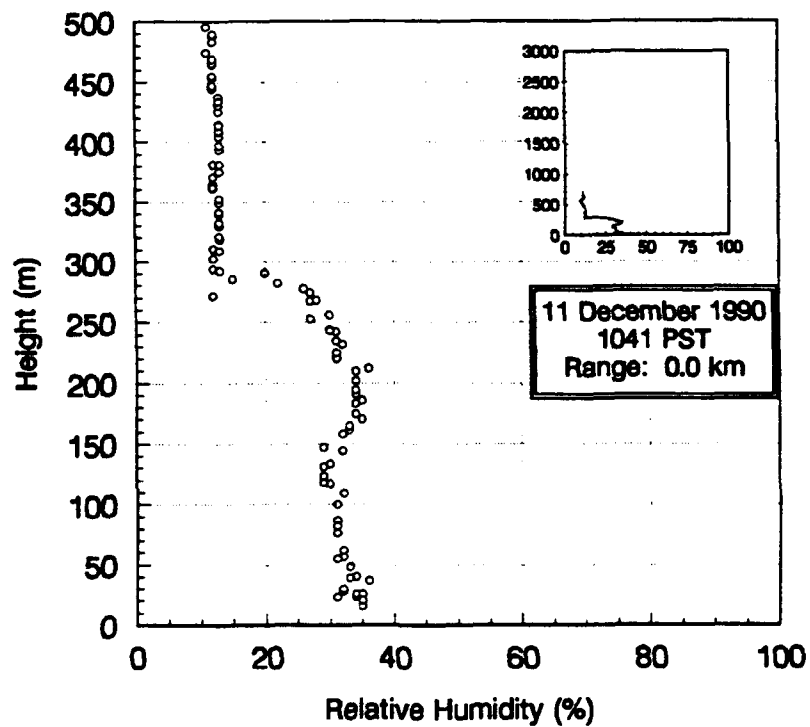


Figure 162. Air temperature versus height for the radiosonde on 12/11/1990 at 10:41 PST.

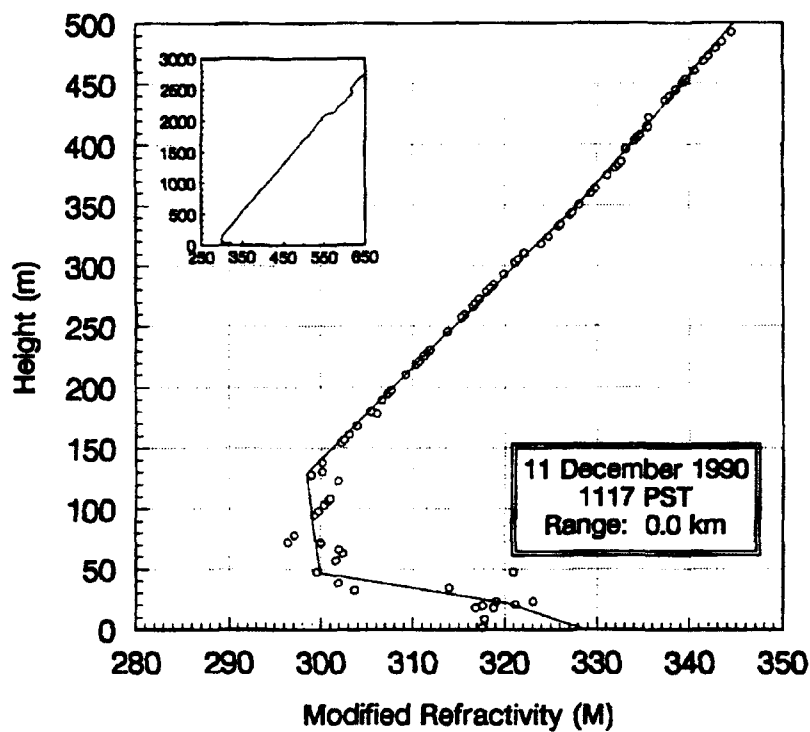


Figure 163. Modified refractivity versus height for the radiosonde on 12/11/1990 at 11:17 PST.

Radar Site
Launch Height: 23 m

Height (m)	M-Units
0.00	328.80
21.51	320.38
46.59	299.92
129.03	298.42
362.01	329.40
541.22	349.25
989.25	410.00

Figure 164. List of modified refractivity versus height for the radiosonde on 12/11/1990 at 11:17 PST.

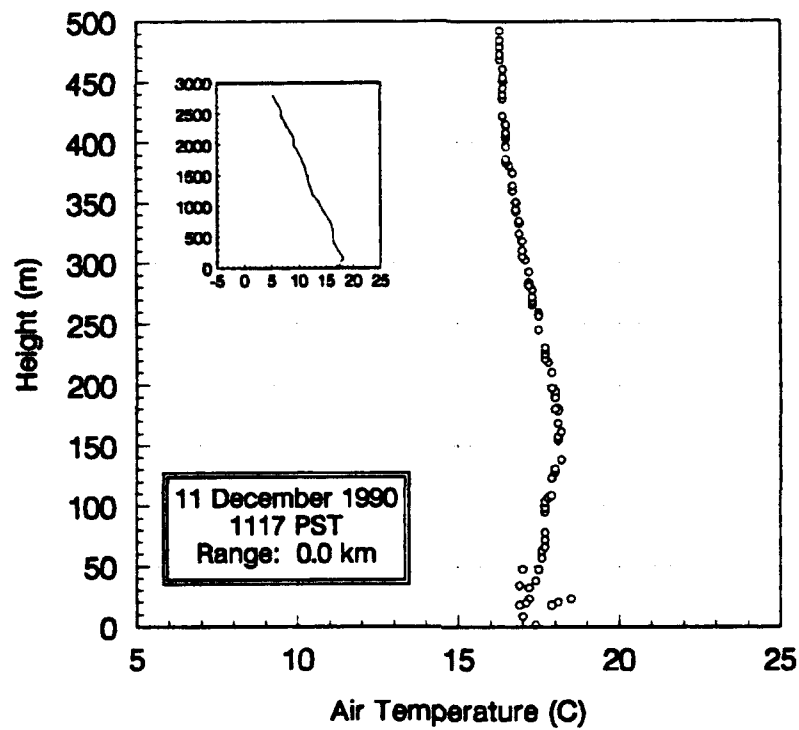


Figure 165. Relative humidity versus height for the radiosonde on 12/11/1990 at 11:17 PST.

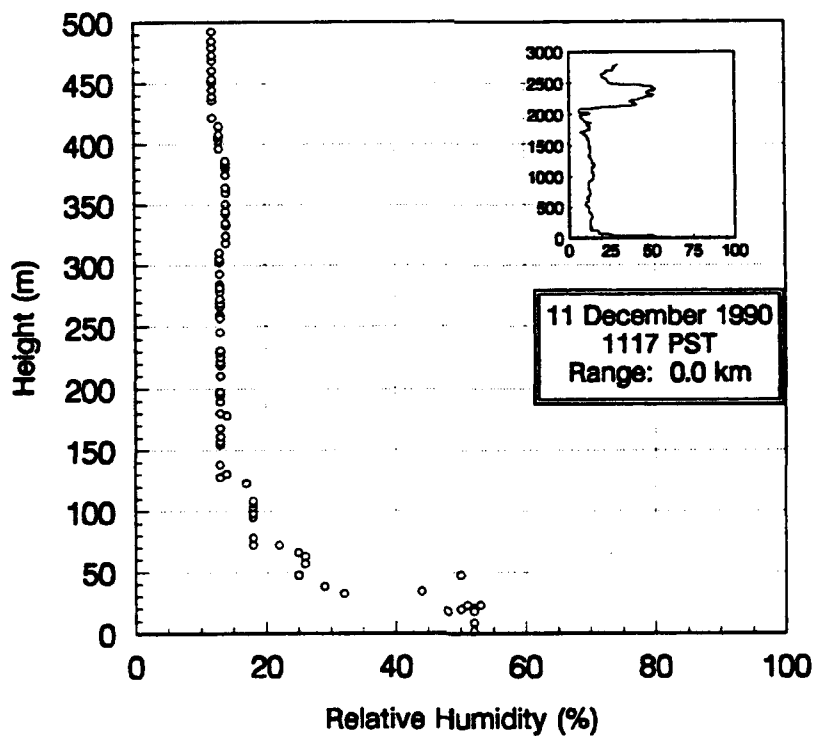


Figure 166. Air temperature versus height for the radiosonde on 12/11/1990 at 11:17 PST.

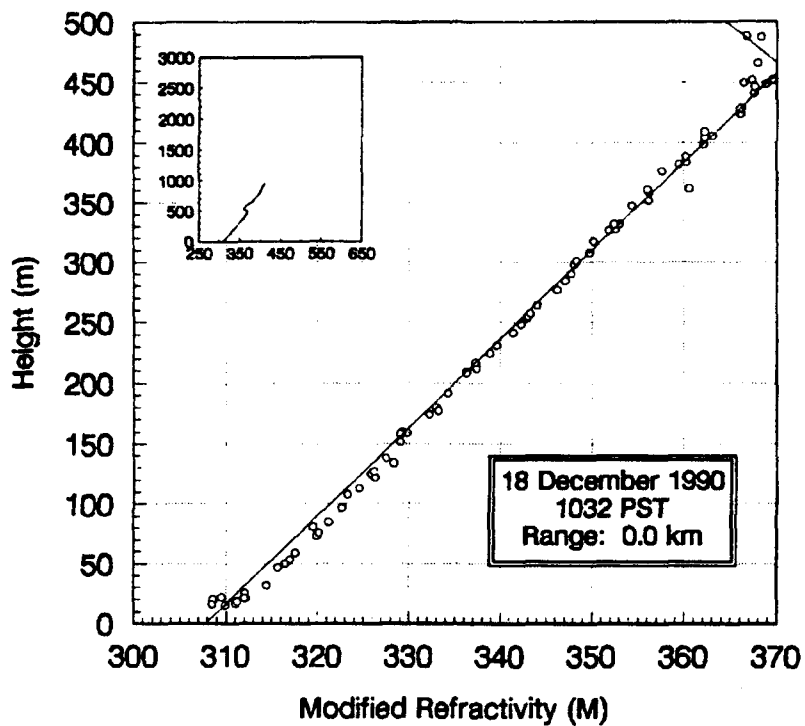


Figure 167. Modified refractivity versus height for the radiosonde on 12/18/1990 at 10:32 PST.

Radar Site
Launch Height: 20 m

Height (m)	M-Units
0.00	307.82
462.37	370.68
530.47	359.55
602.15	367.67
634.41	377.59
817.20	401.35
885.30	403.46
956.99	411.88

Figure 168. List of modified refractivity versus height for the radiosonde on 12/18/1990 at 10:32 PST.

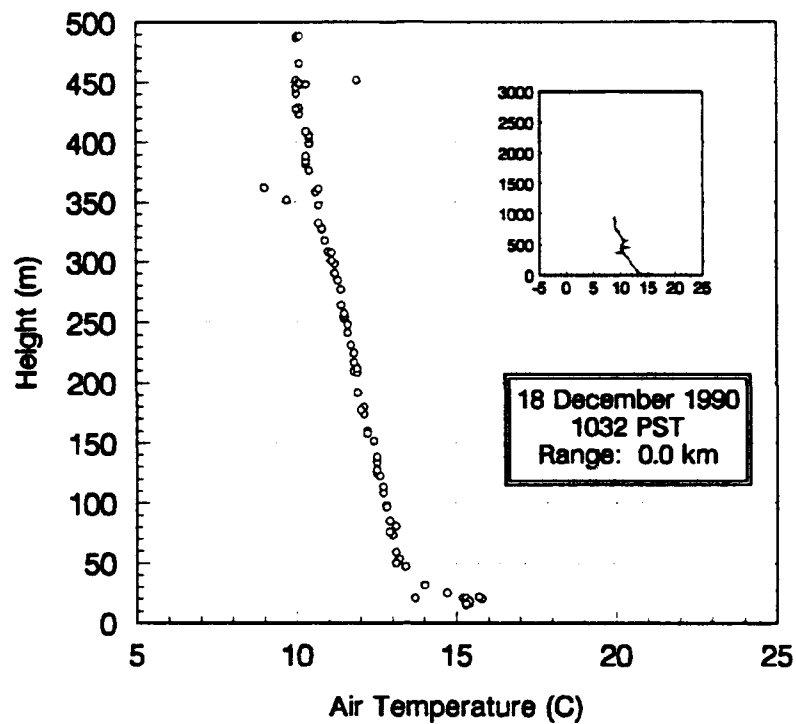


Figure 169. Relative humidity versus height for the radiosonde on 12/18/1990 at 10:32 PST.

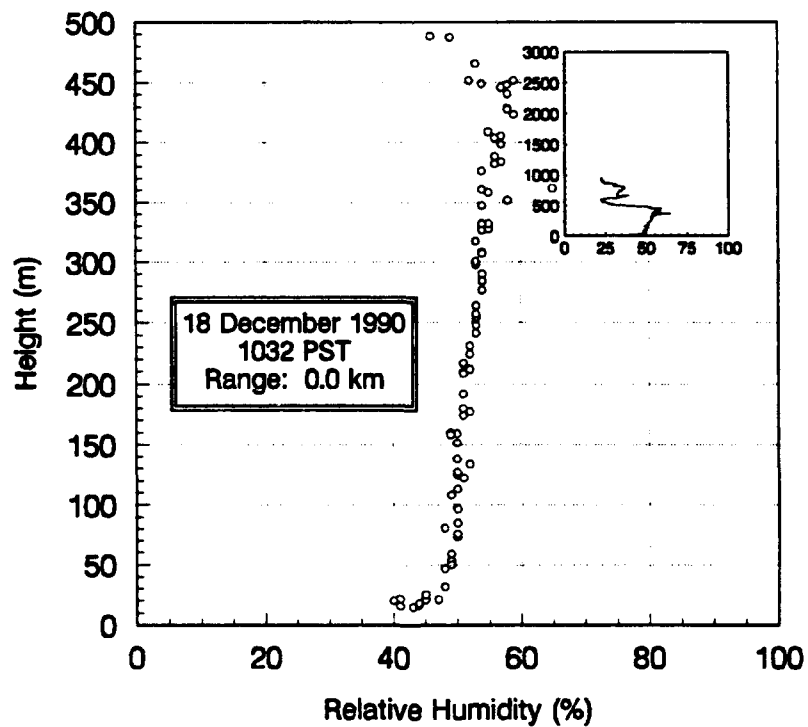


Figure 170. Air temperature versus height for the radiosonde on 12/18/1990 at 10:32 PST.

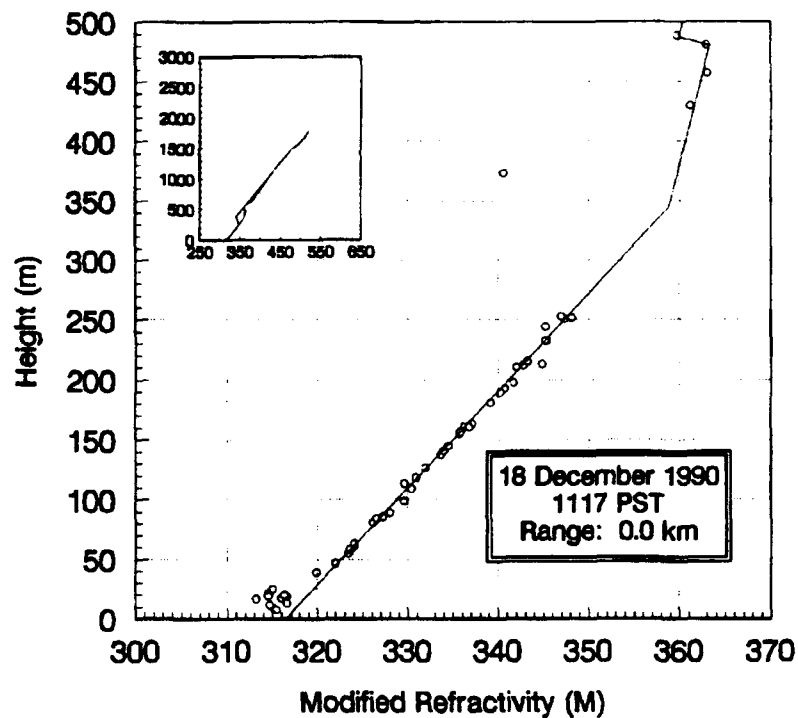


Figure 171. Modified refractivity versus height for the radiosonde on 12/18/1990 at 11:17 PST.

Radar Site
Launch Height: 20 m

Height (m)	M-Units
0.00	316.43
232.97	345.30
344.09	358.83
480.29	363.35
487.46	360.04
555.56	361.84
598.57	369.66
663.08	383.50
996.42	416.88

Figure 172. List of modified refractivity versus height for the radiosonde on 12/18/1990 at 11:17 PST.

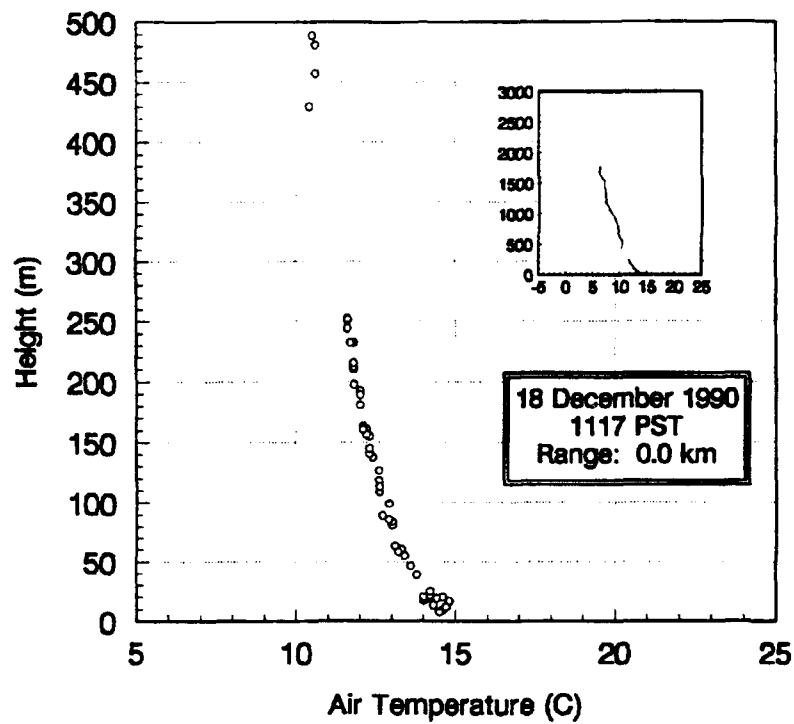


Figure 173. Relative humidity versus height for the radiosonde on 12/18/90 at 11:17 PST.

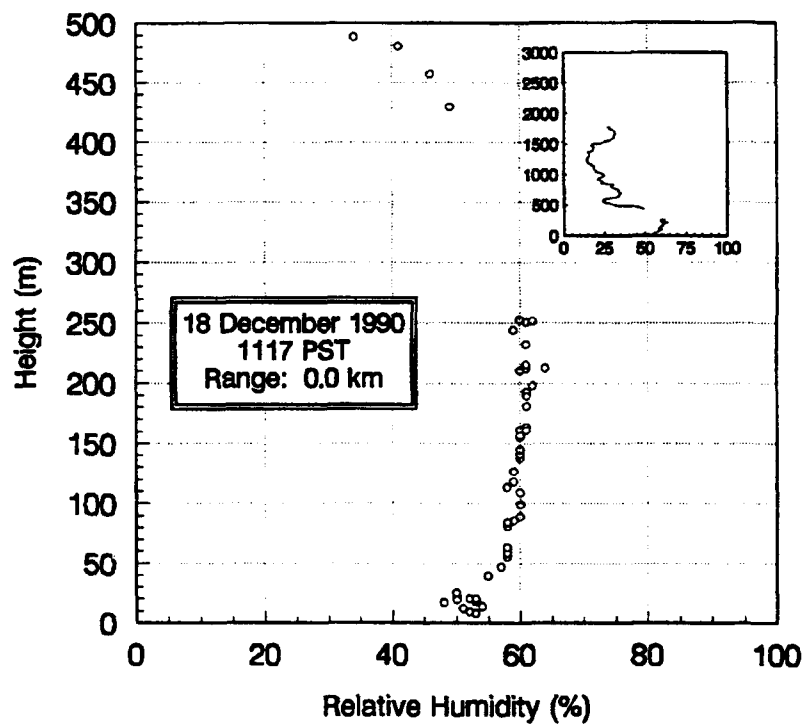


Figure 174. Air temperature versus height for the radiosonde on 12/18/90 at 11:17 PST.

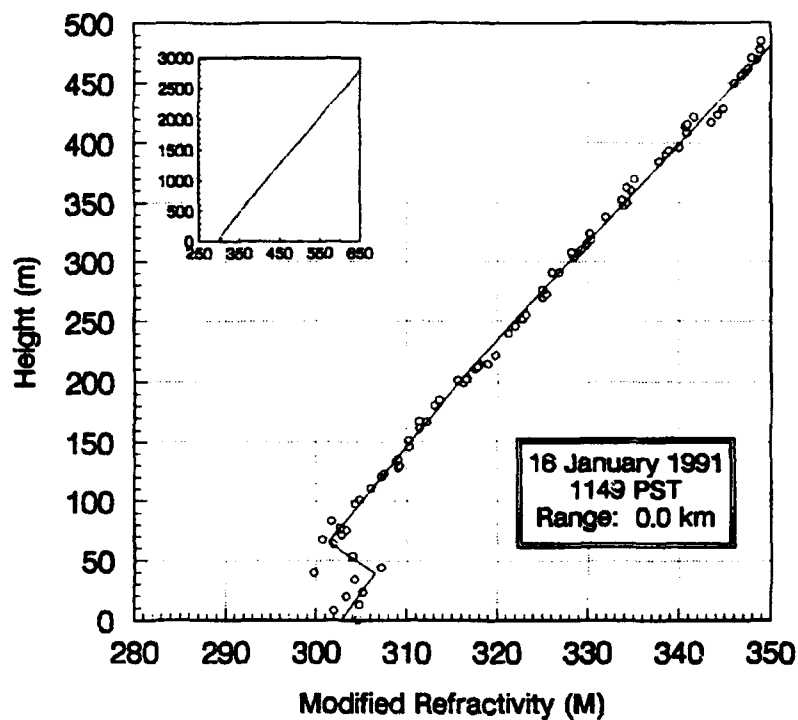


Figure 175. Modified refractivity versus height for the radiosonde on 01/16/1991 at 11:49 PST.

Radar Site	
Launch Height: 23 m	
Height (m)	M-Units
0.00	302.82
39.43	306.43
64.52	301.32
197.13	315.45
609.32	365.68
978.49	414.10

Figure 176. List of modified refractivity versus height for the radiosonde on 01/16/1991 at 11:49 PST.

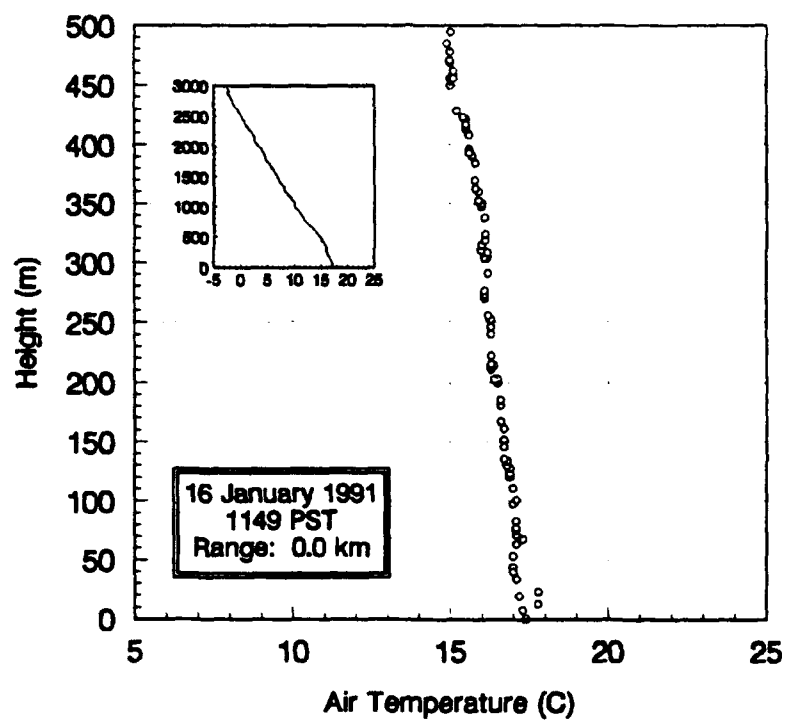


Figure 177. Relative humidity versus height for the radiosonde on 01/16/1991 at 11:49 PST.

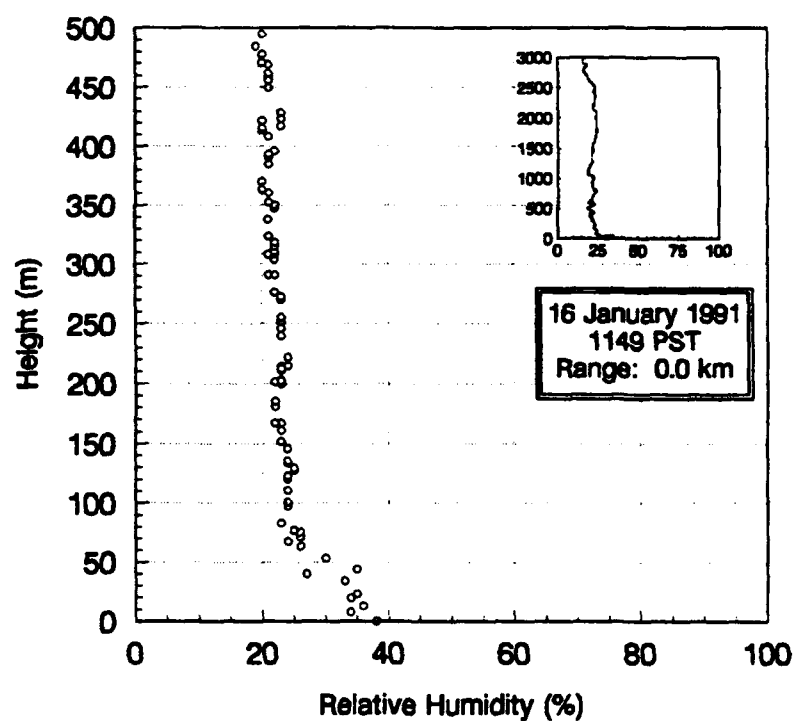


Figure 178. Air temperature versus height for the radiosonde on 01/16/1991 at 11:49 PST.

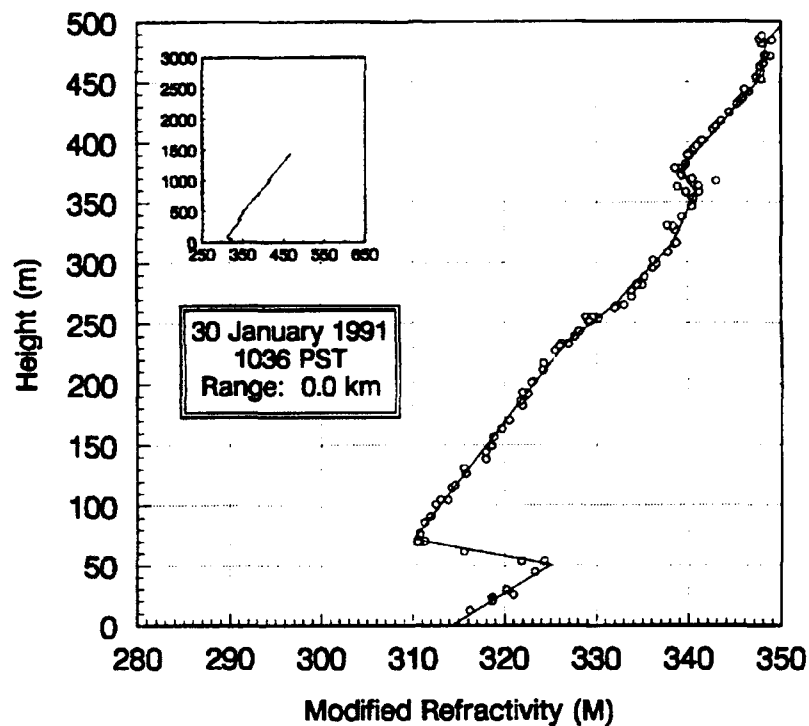


Figure 179. Modified refractivity versus height for the radiosonde on 01/30/1991 at 10:36 PST.

Radar Site
Launch Height: 23 m

Height (m)	M-Units
0.00	314.25
50.18	325.08
71.68	310.04
232.97	326.58
265.23	331.99
315.41	338.31
358.42	340.71
376.34	339.21
451.61	347.63
483.87	348.53
634.41	367.48
989.25	415.00

Figure 180. List of modified refractivity versus height for the radiosonde on 01/30/1991 at 10:36 PST.

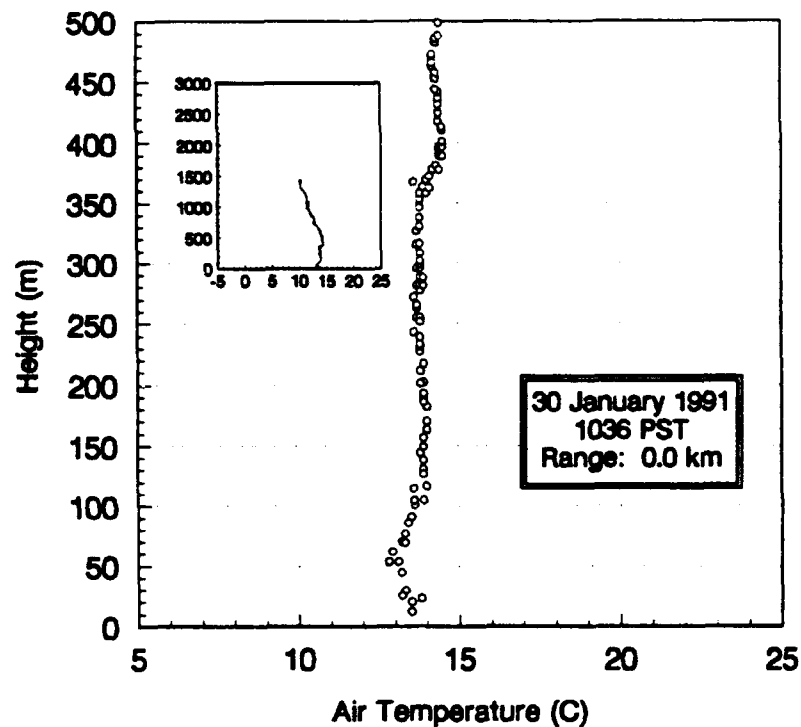


Figure 181. Relative humidity versus height for the radiosonde on 01/30/1991 at 10:36 PST.

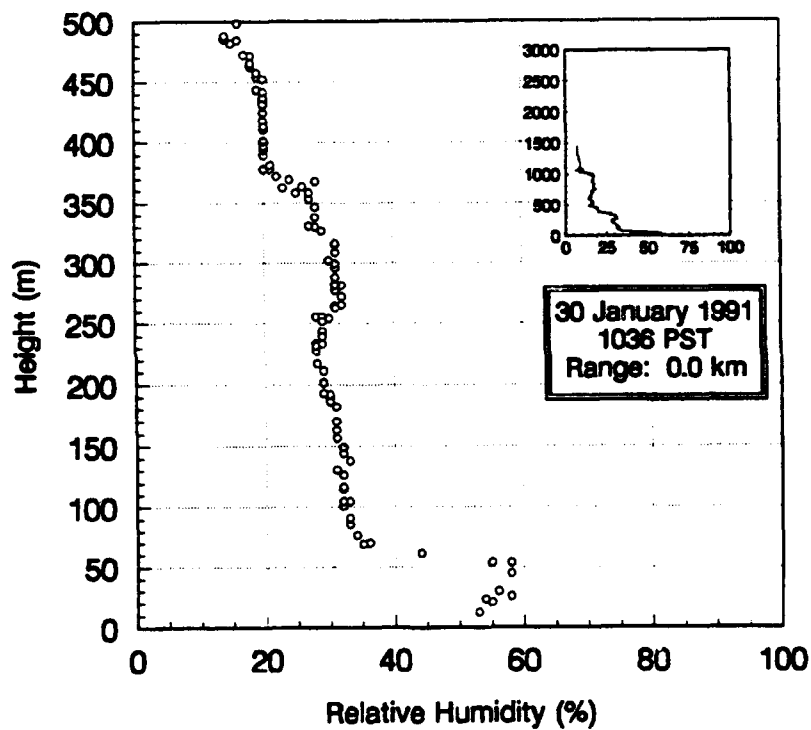


Figure 182. Air temperature versus height for the radiosonde on 01/30/1991 at 10:36 PST.

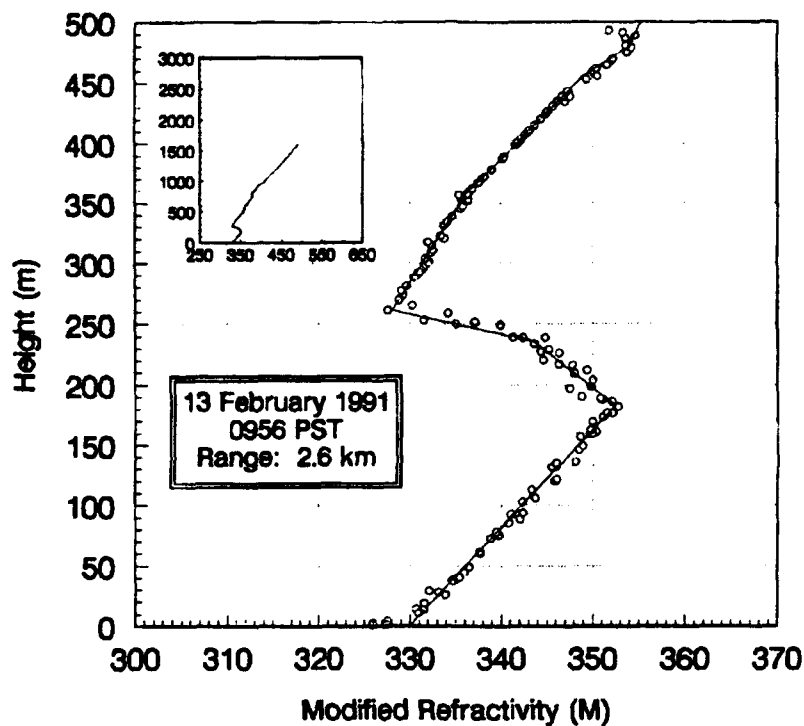


Figure 183. Modified refractivity versus height for the radiosonde on 02/13/1991 at 09:56 PST.

Boat 2.6 km @ 266
Launch Height: 1 m

Height (m)	M-Units
0.00	329.92
182.80	352.48
236.56	343.46
261.65	328.12
358.42	336.24
455.20	348.87
480.29	353.98
594.98	361.20
749.10	378.95
810.04	379.25
931.90	393.38
1000.00	410.23

Figure 184. List of modified refractivity versus height for the radiosonde on 02/13/1991 at 09:56 PST.

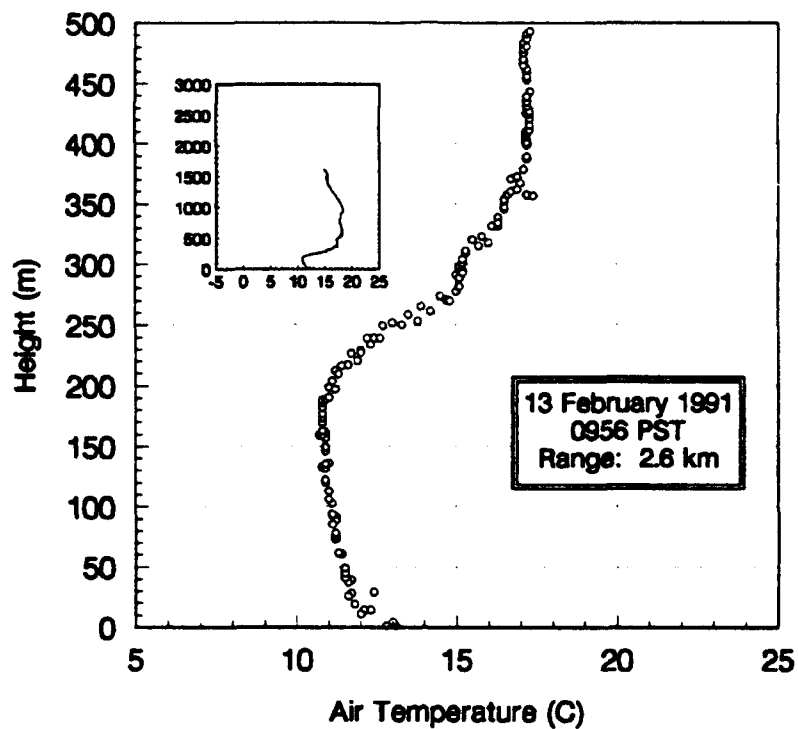


Figure 185. Relative humidity versus height for the radiosonde on 02/13/1991 at 09:56 PST.

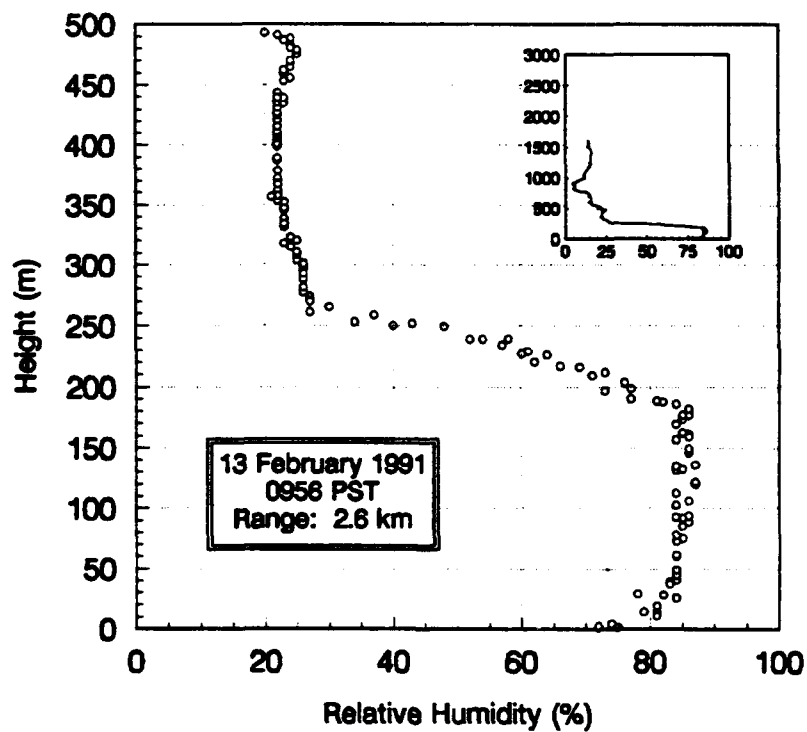


Figure 186. Air temperature versus height for the radiosonde on 02/13/1991 at 09:56 PST.

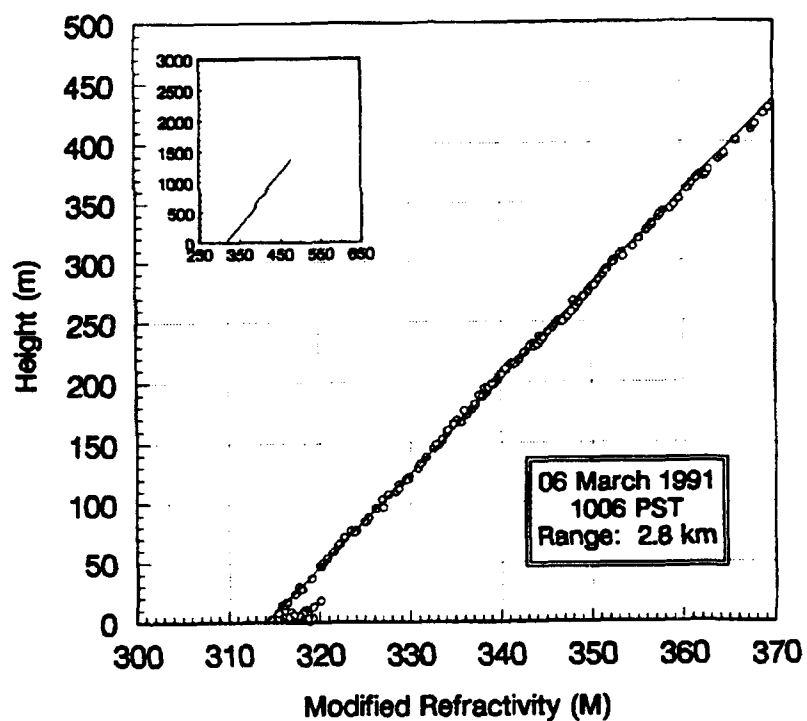


Figure 187. Modified refractivity versus height for the radiosonde on 03/06/1991 at 10:06 PST.

Boat 2.8 km @ 273
Launch Height: 1 m

Height (m)	M-Units
0.00	314.02
555.56	385.30
655.91	388.31
752.69	400.34
777.78	406.05
956.99	425.00

Figure 188. List of modified refractivity versus height for the radiosonde on 03/06/1991 at 10:06 PST.

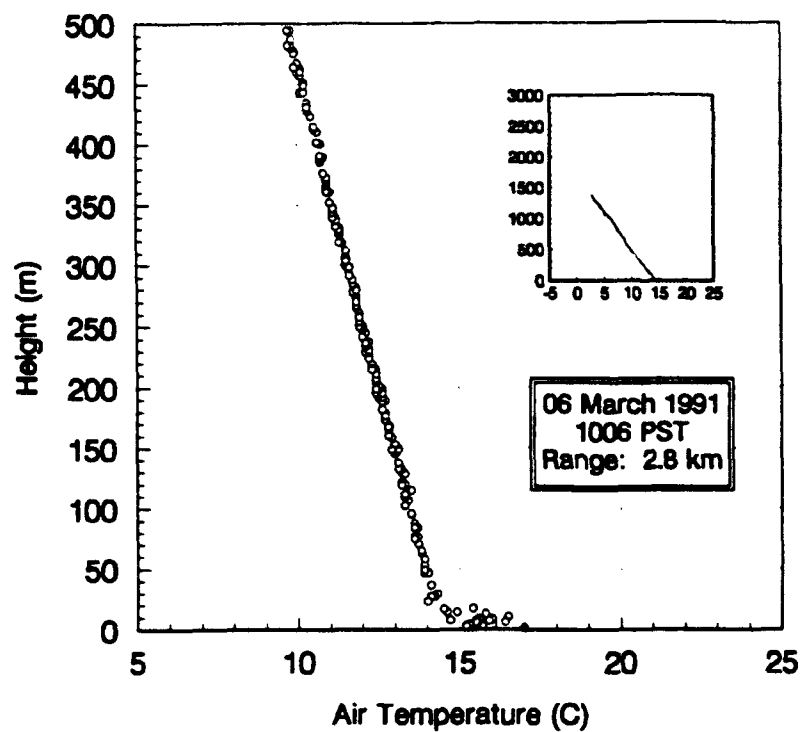


Figure 189. Relative humidity versus height for the radiosonde on 03/06/1991 at 10:06 PST.

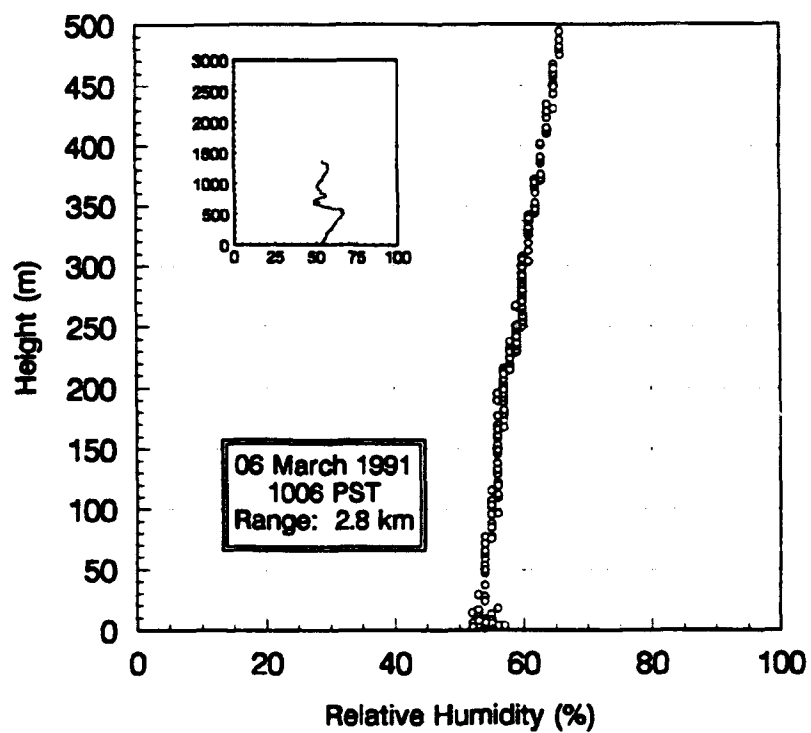


Figure 190. Air temperature versus height for the radiosonde on 03/11/1991 at 10:06 PST.

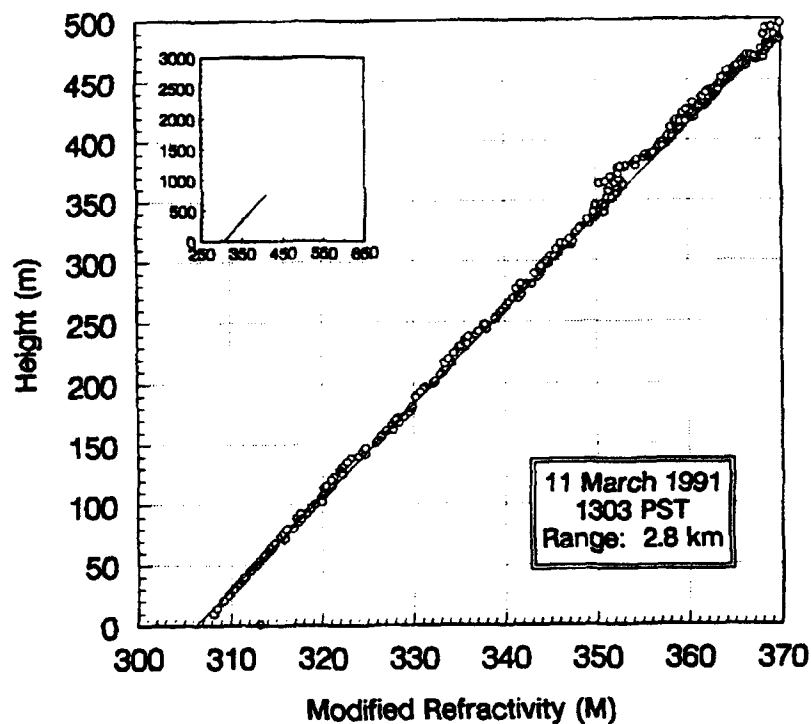


Figure 191. Modified refractivity versus height for the radiosonde on 03/11/1991 at 13:03 PST.

Boat 2.8 km @ 276
Launch Height: 1 m

Height (m)	M-Units
0.00	306.13
767.03	406.28

Figure 192. List of modified refractivity versus height for the radiosonde on 03/11/1991 at 13:03 PST.

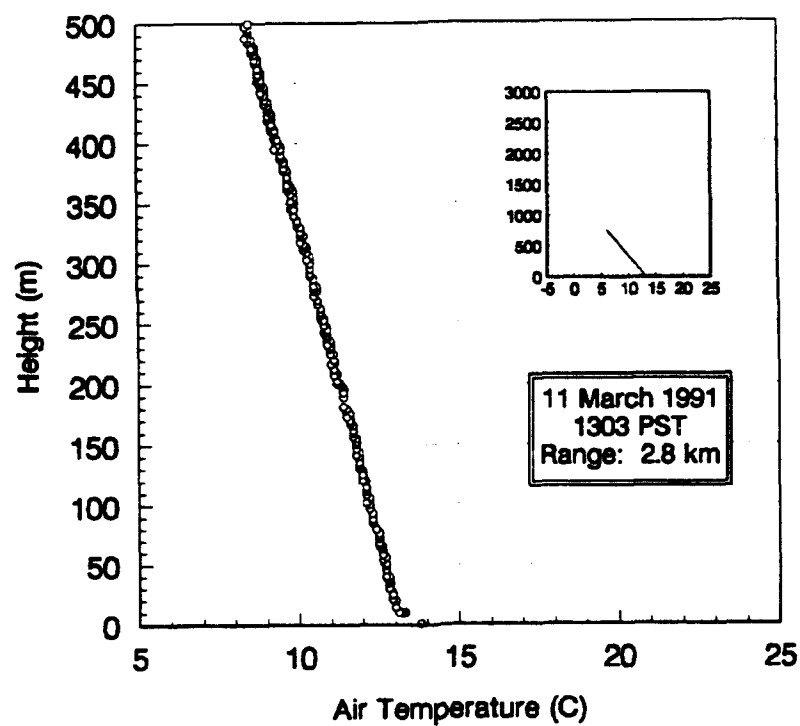


Figure 193. Relative humidity versus height for the radiosonde on 03/11/1991 at 13:03 PST.

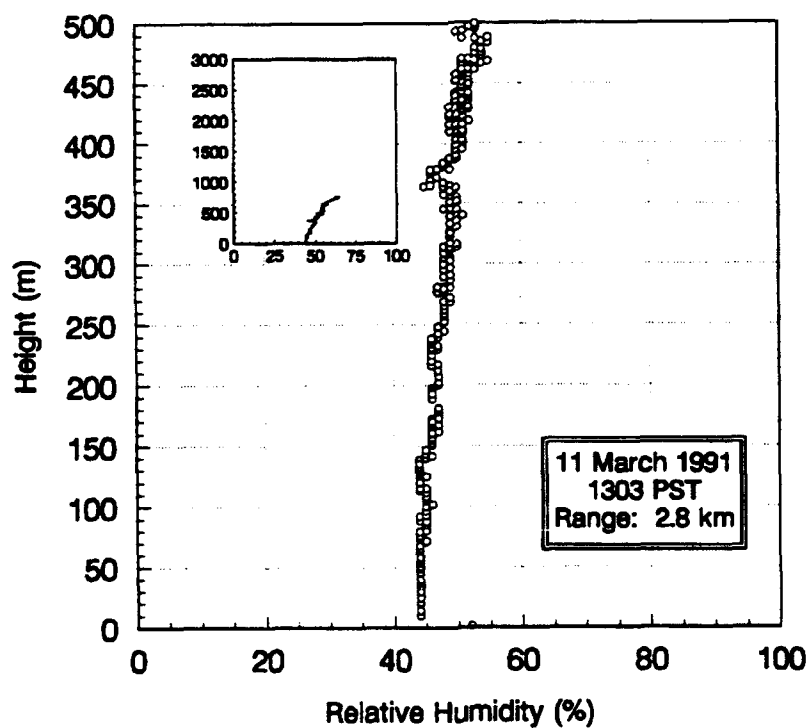


Figure 194. Air temperature versus height for the radiosonde on 03/11/1991 at 13:03 PST.

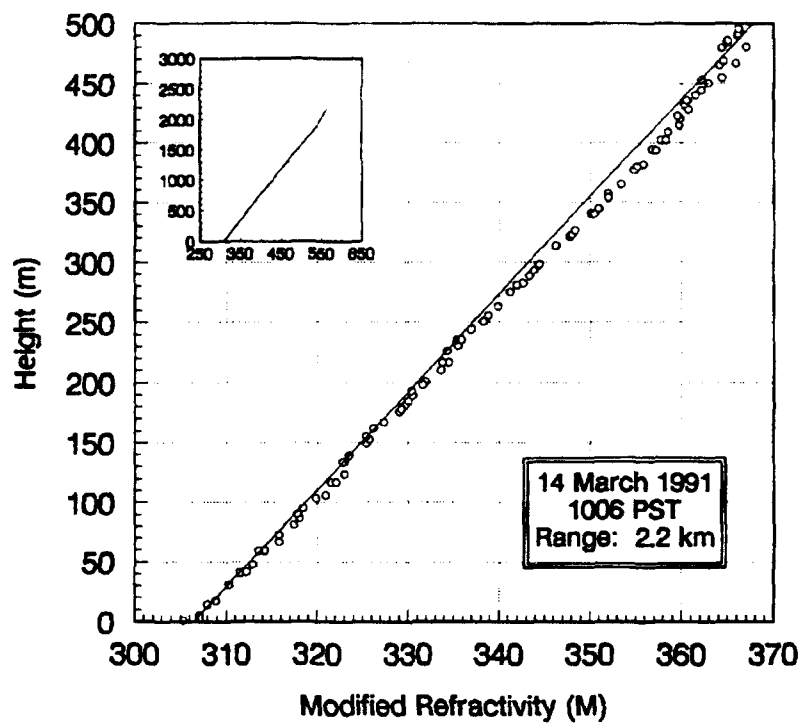


Figure 195. Modified refractivity versus height for the radiosonde on 03/14/1991 at 10:06 PST.

Boat 2.2 km @ 272
Launch Height: 1 m

Height (m)	M-Units
0.00	306.43
885.30	415.00

Figure 196. List of modified refractivity versus height for the radiosonde on 03/14/1991 at 10:06 PST.

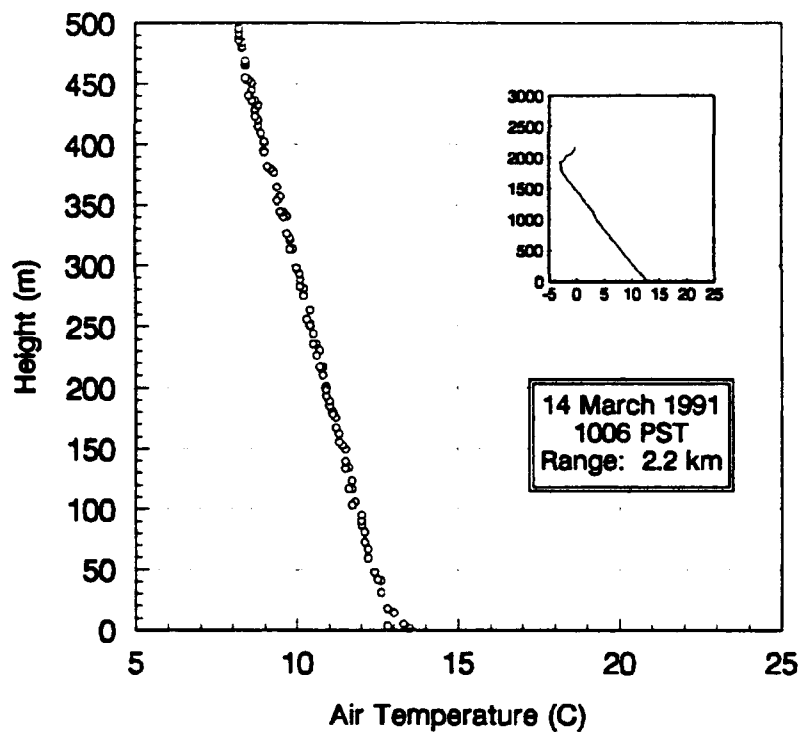


Figure 197. Relative humidity versus height for the radiosonde on 03/14/1991 at 10:06 PST.

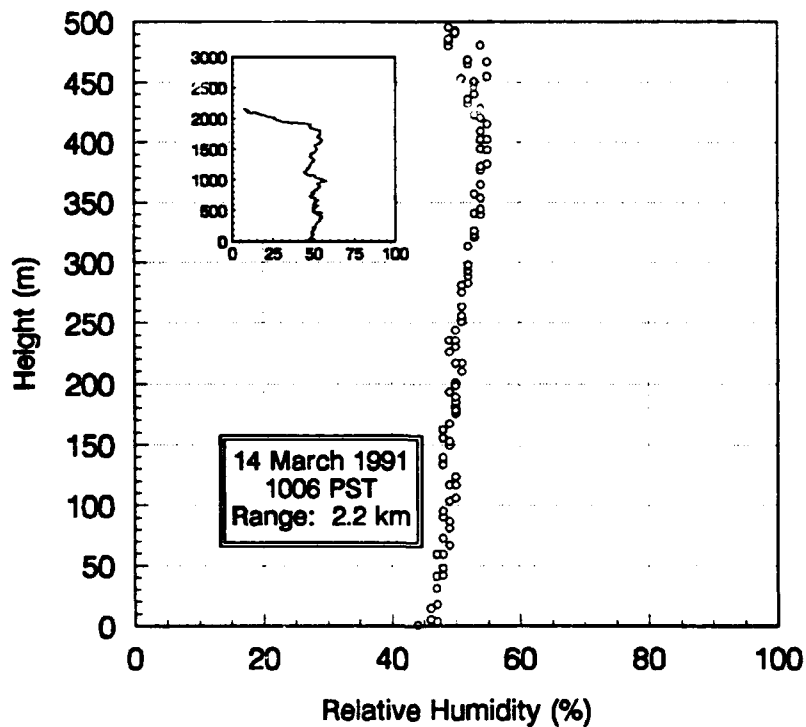


Figure 198. Air temperature versus height for the radiosonde on 03/14/1991 at 10:06 PST.

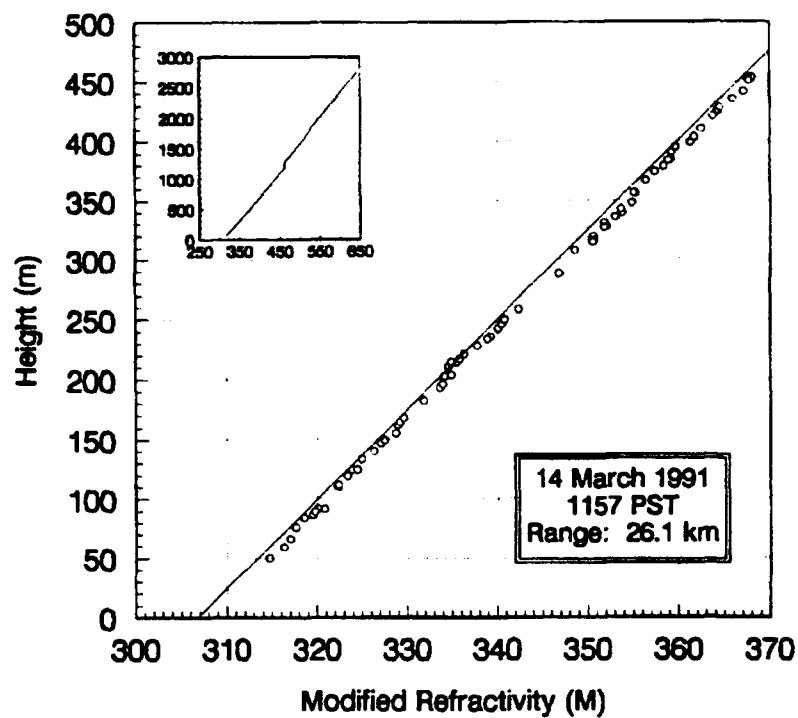


Figure 199. Modified refractivity versus height for the radiosonde on 03/14/1991 at 11:56 PST.

Boat 26.1 km @ 269
Launch Height: 50 m

Height (m)	M-Units
0.00	306.73
813.62	415.00

Figure 200. List of modified refractivity versus height for the radiosonde on 03/14/1991 at 11:56 PST.

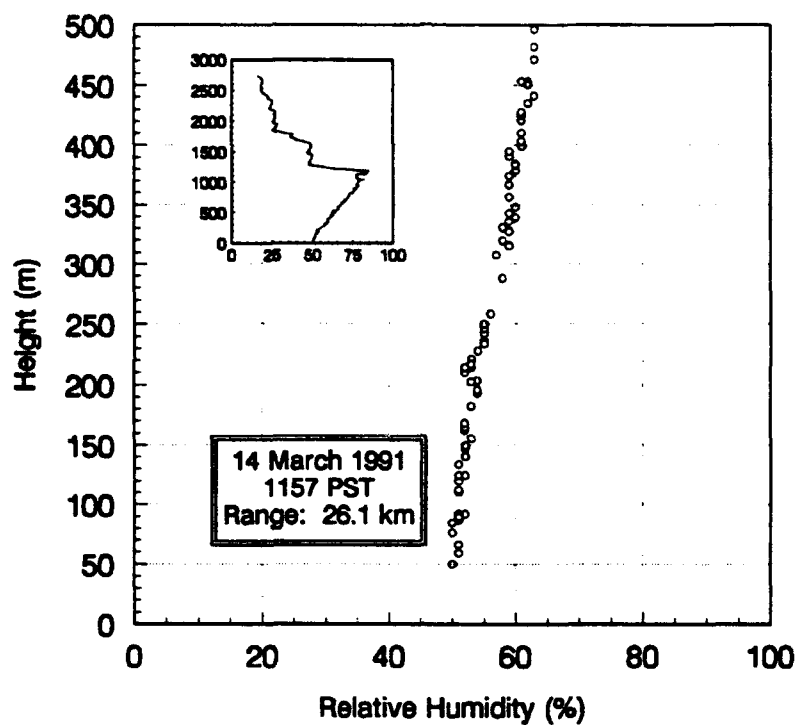


Figure 201. Relative humidity versus height for the radiosonde on 03/14/1991 at 11:56 PST.

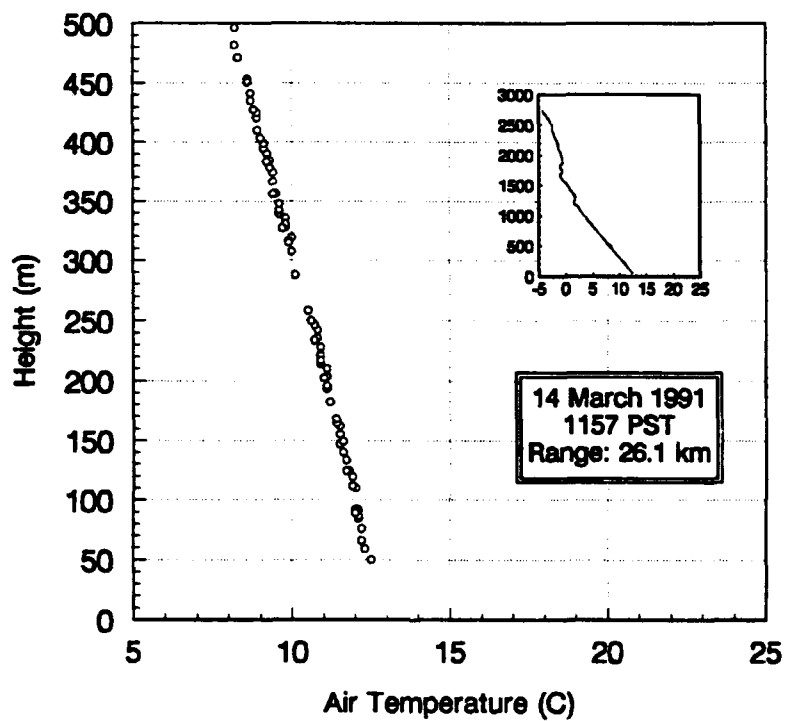


Figure 202. Air temperature versus height for the radiosonde on 03/14/1991 at 11:56 PST.

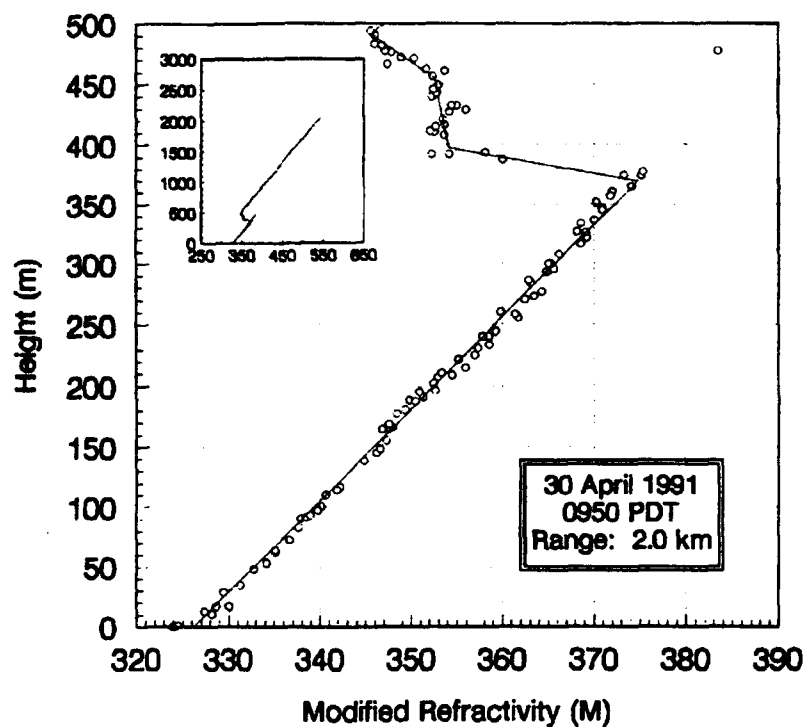


Figure 203. Modified refractivity versus height for the radiosonde on 04/30/1991 at 09:50 PDT.

Boat 2.0 km @ 270
Launch Height: 50 m

Height (m)	M-Units
0.00	306.73
813.62	415.00

Figure 204. List of modified refractivity versus height for the radiosonde on 04/30/1991 at 09:50 PDT.

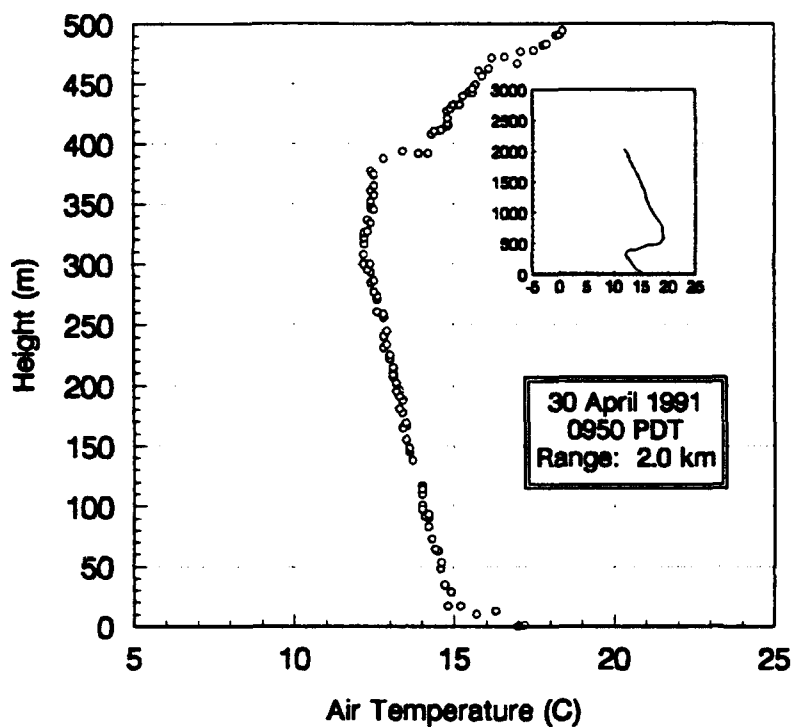


Figure 205. Relative humidity versus height for the radiosonde on 04/30/1991 at 09:50 PDT.

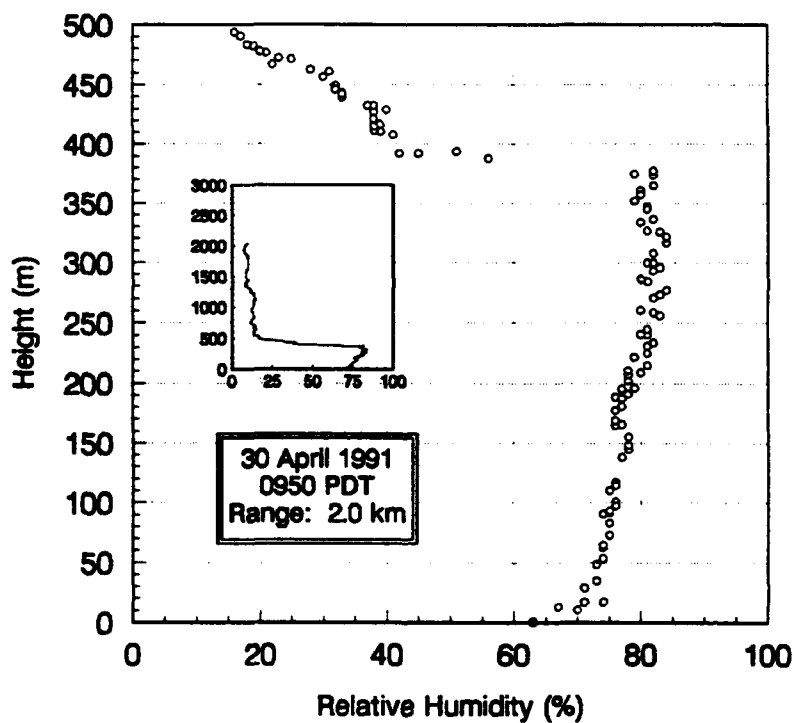


Figure 206. Air temperature versus height for the radiosonde on 04/30/1991 at 09:50 PDT.

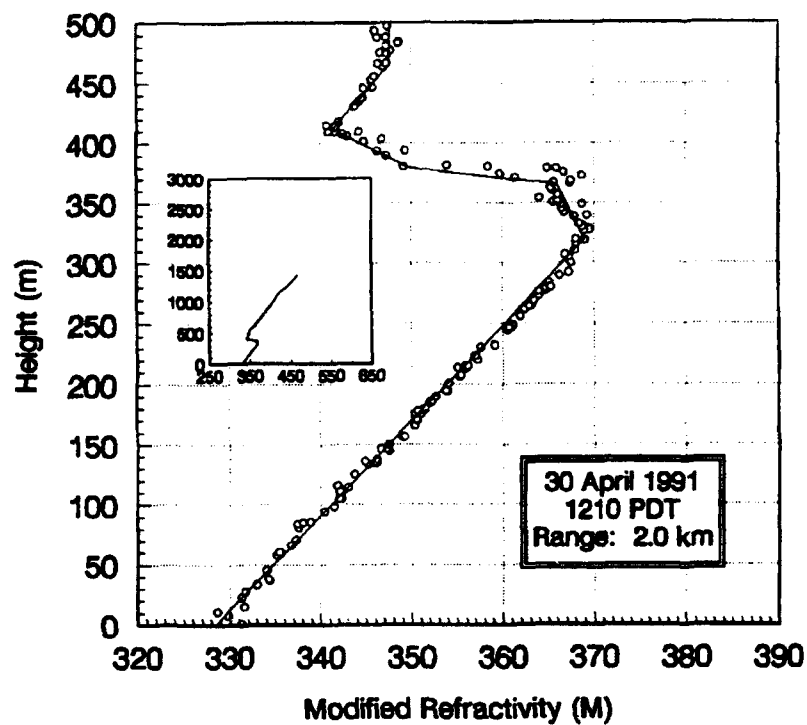


Figure 207. Modified refractivity versus height for the radiosonde on 04/30/1991 at 12:10 PDT.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	328.38
319.00	368.98
365.59	365.98
379.93	349.74
412.19	341.32
465.95	347.63
505.38	347.63
544.80	350.34
620.07	363.27
630.82	360.86
659.50	364.47
666.67	368.08
1000.00	408.38

Figure 208. List of modified refractivity versus height for the radiosonde on 04/30/1991 at 12:10 PDT.

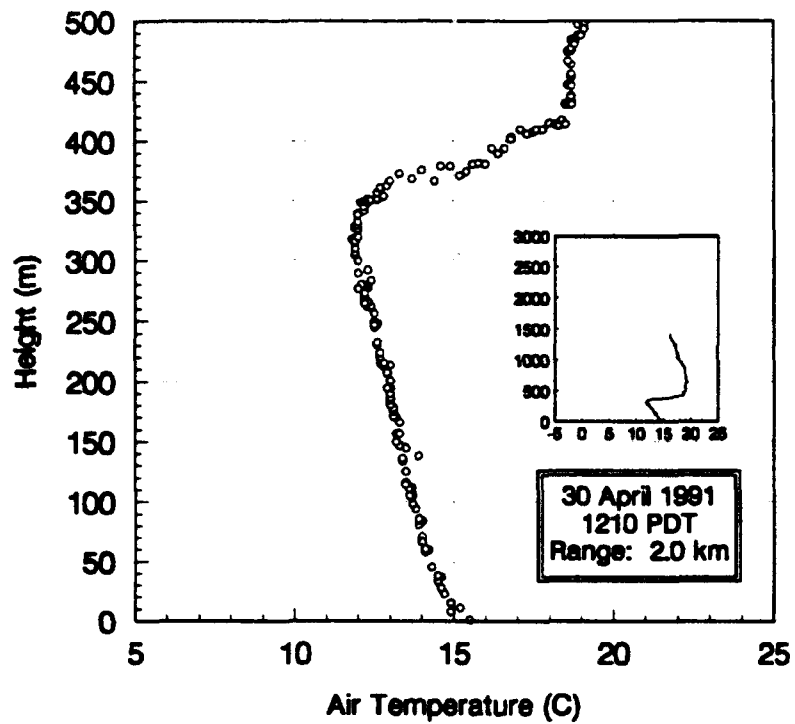


Figure 209. Relative humidity versus height for the radiosonde on 04/30/1991 at 12:10 PDT.

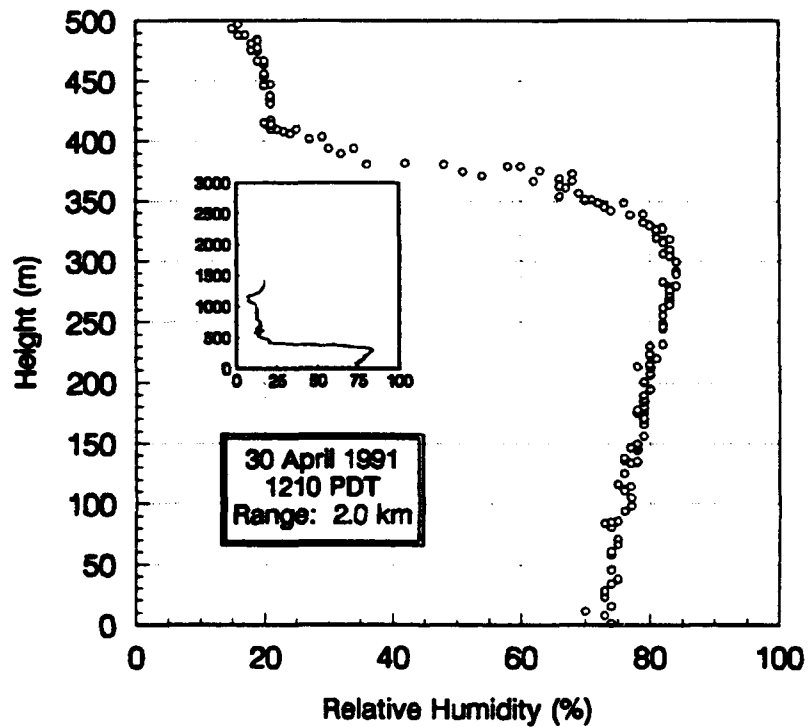


Figure 210. Air temperature versus height for the radiosonde on 04/30/1991 at 12:10 PDT.

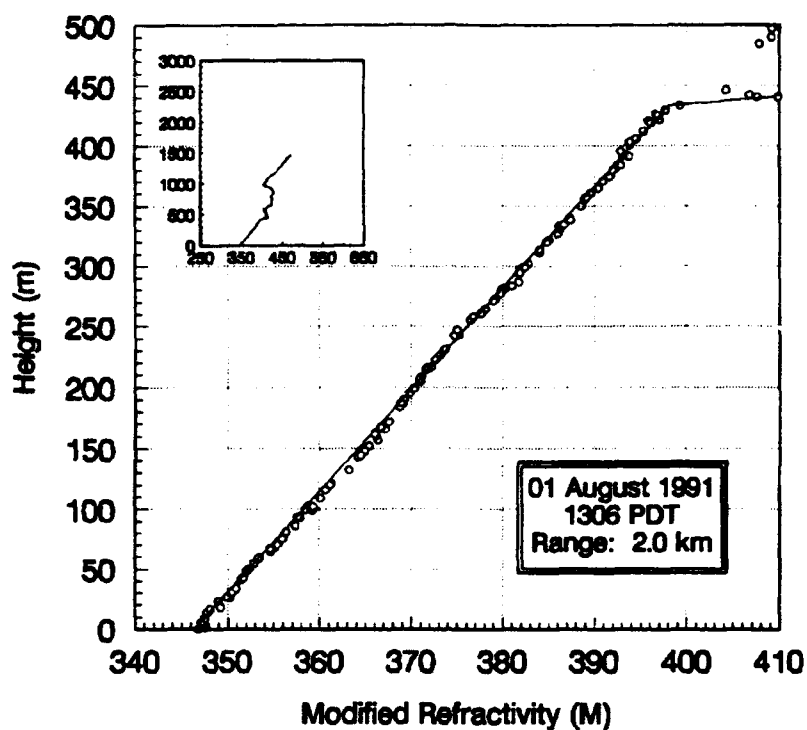


Figure 211. Modified refractivity versus height for the radiosonde on 08/01/1991 at 13:06 PDT.

Boat 2.0 km @ 268
Launch Height: 1 m

Height (m)	M-Units
0.00	346.32
433.69	398.05
440.86	409.47
469.53	417.29
491.04	410.08
587.81	406.47
648.75	418.20
666.67	424.21
767.03	425.11
784.95	421.50
856.63	429.02
946.24	420.60
960.57	409.17
992.83	403.16

Figure 212. List of modified refractivity versus height for the radiosonde on 08/01/1991 at 13:06 PDT.

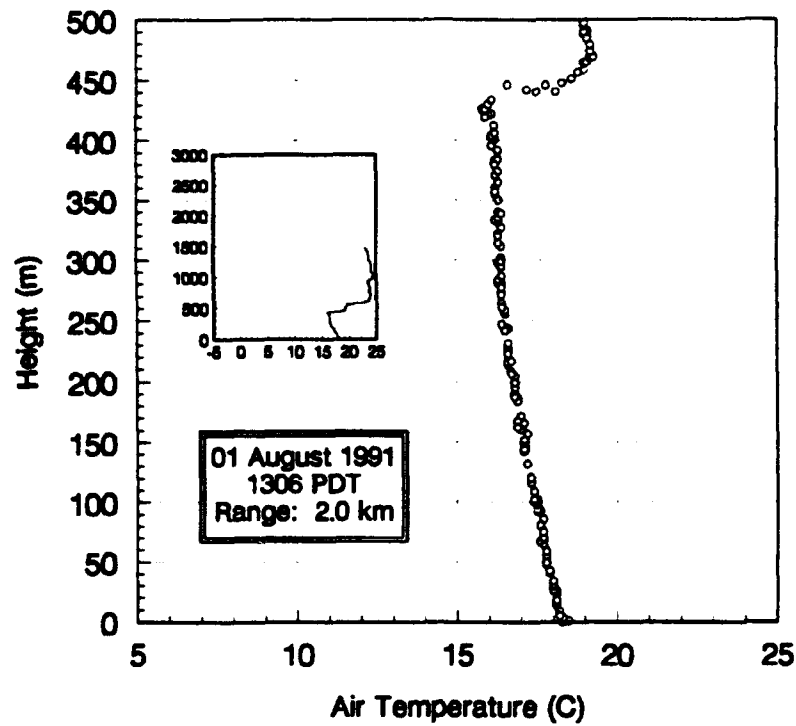


Figure 213. Relative humidity versus height for the radiosonde on 08/01/1991 at 13:06 PDT.

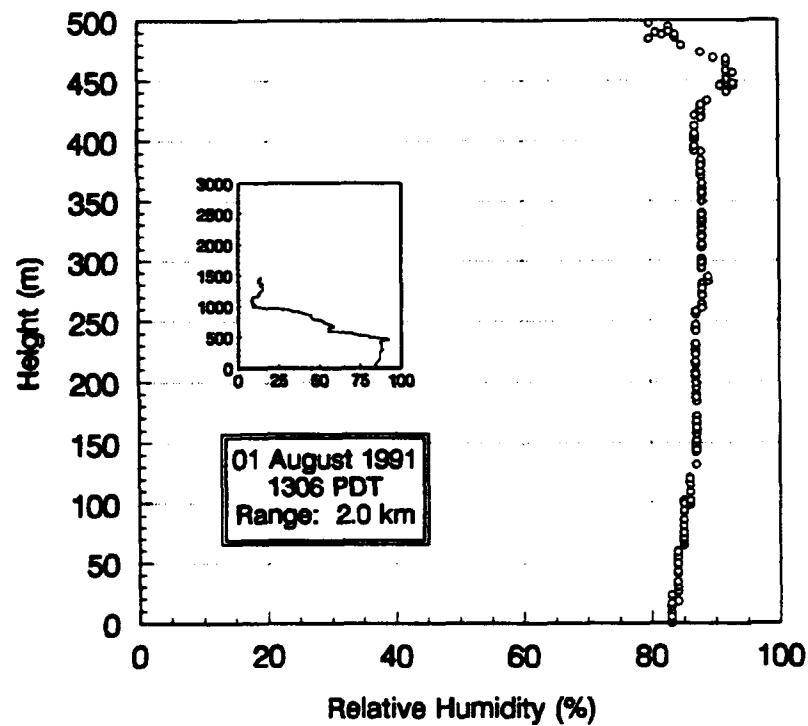


Figure 214. Air temperature versus height for the radiosonde on 08/01/1991 at 13:06 PDT.

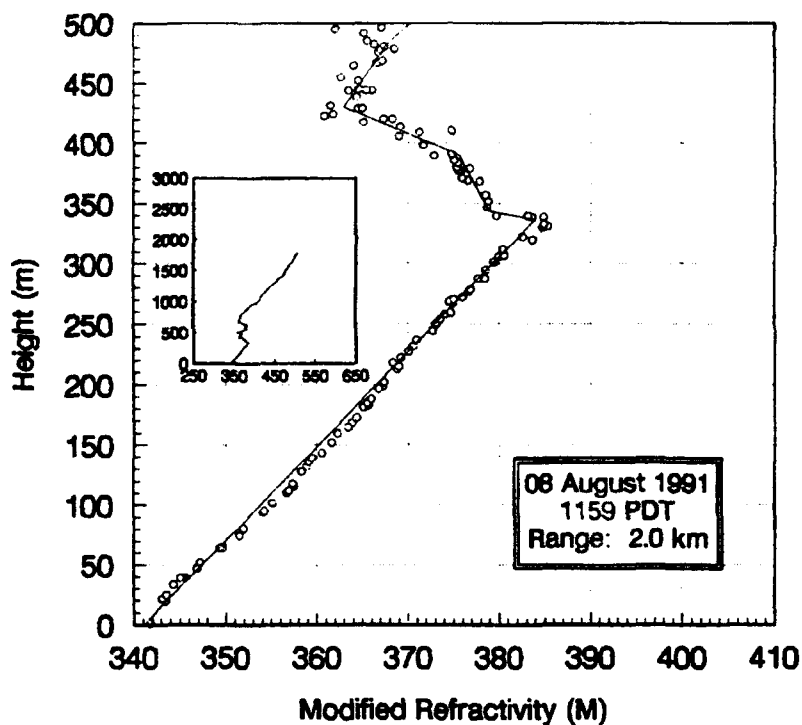


Figure 215. Modified refractivity versus height for the radiosonde on 08/08/1991 at 11:59 PDT.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	341.02
336.92	384.02
344.09	378.91
390.68	375.60
430.11	362.97
480.29	367.48
591.40	382.82
605.73	378.01
634.41	381.62
663.08	364.77
774.19	366.58
910.39	385.53
1000.00	408.68

Figure 216. List of modified refractivity versus height for the radiosonde on 08/08/1991 at 11:59 PDT.

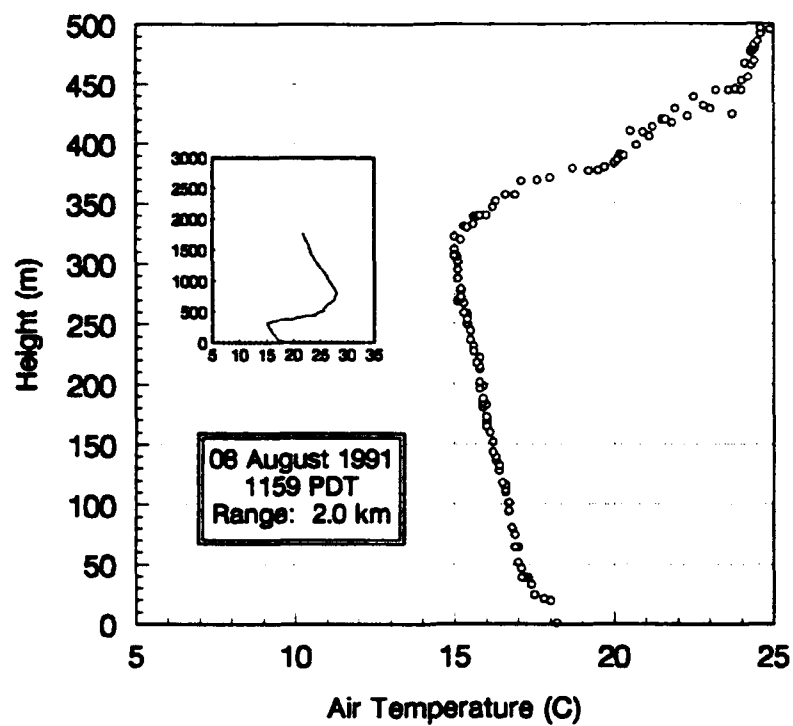


Figure 217. Relative humidity versus height for the radiosonde on 08/08/1991 at 11:59 PDT.

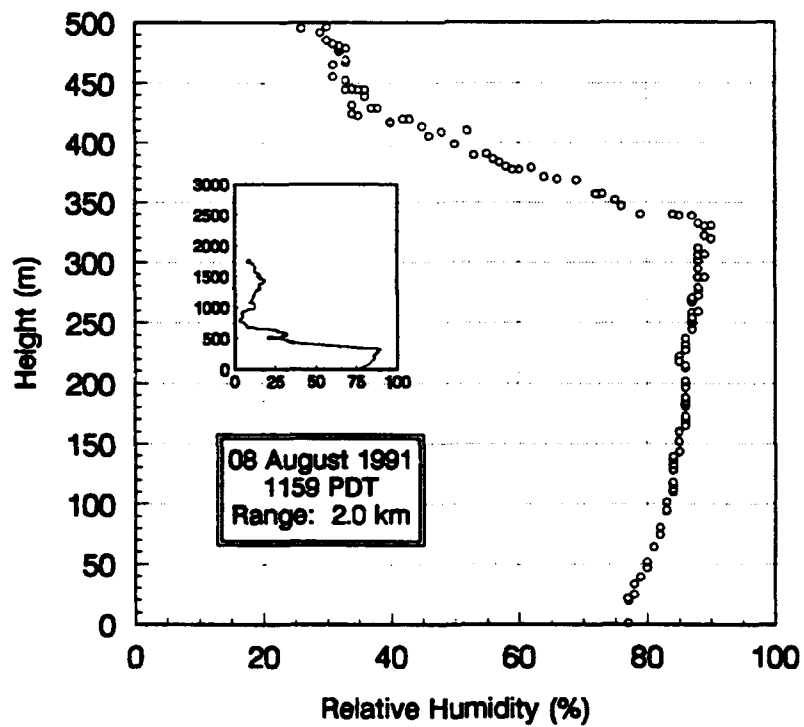


Figure 218. Air temperature versus height for the radiosonde on 08/08/1991 at 11:59 PDT.

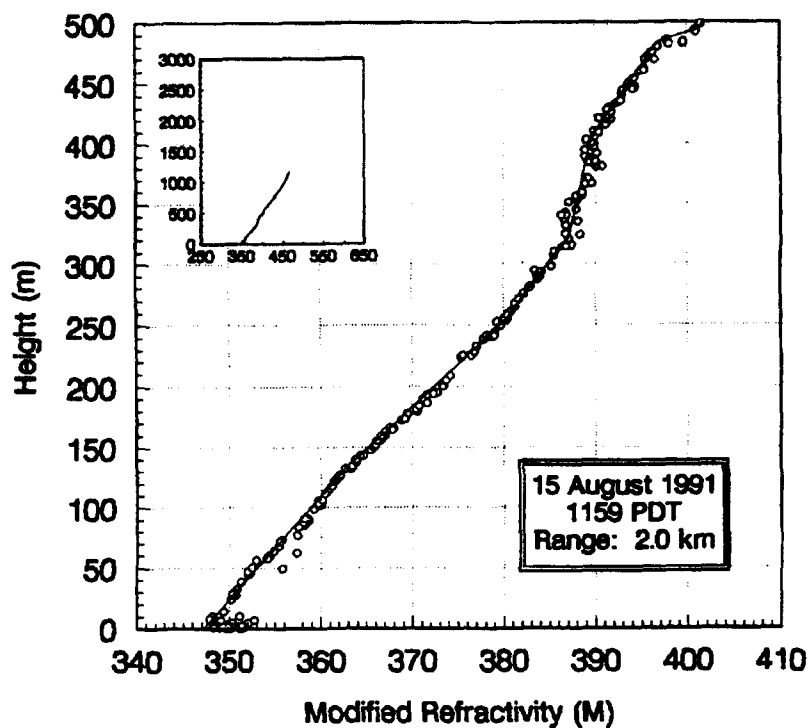


Figure 219. Modified refractivity versus height for the radiosonde on 08/08/1991 at 11:59 PDT.

Boat 2.0 km @ 277
Launch Height: 1 m

Height (m)	M-Units
0.00	347.22
129.03	362.26
254.48	380.30
322.58	387.22
405.02	389.62
483.87	396.84
494.62	401.35
569.89	405.86
1000.00	454.59

Figure 220. List of modified refractivity versus height for the radiosonde on 08/15/1991 at 11:59 PDT.

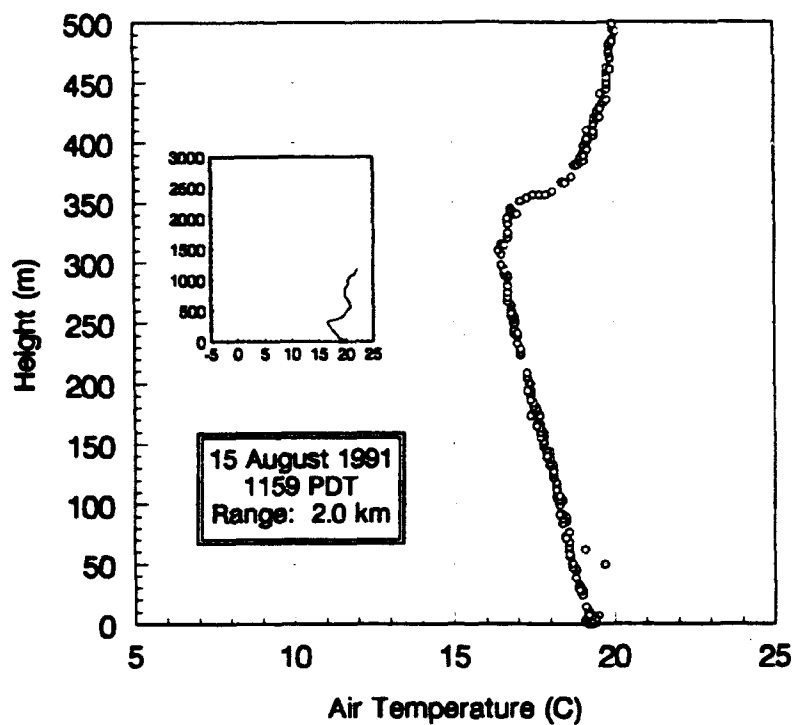


Figure 221. Relative humidity versus height for the radiosonde on 08/15/1991 at 11:59 PDT.

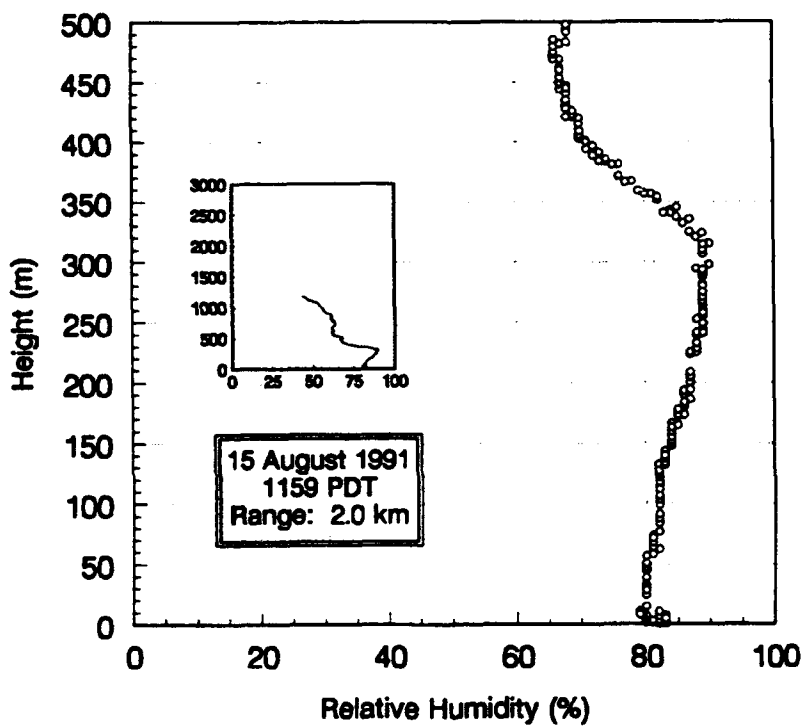


Figure 222. Air temperature versus height for the radiosonde on 08/15/1991 at 11:59 PDT.

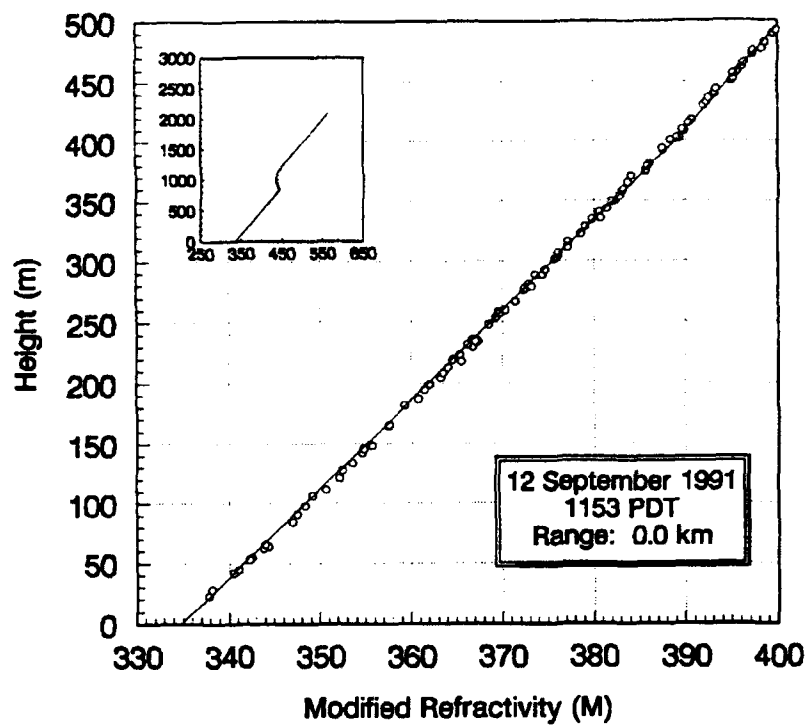


Figure 223. Modified refractivity versus height for the radiosonde on 09/12/1991 at 11:53 PDT.

Radar Site	
Launch Height: 23 m	
Height (m)	M-Units
0.00	334.81
397.85	388.65
548.39	406.09
835.13	442.18
956.99	432.56
1000.00	437.07

Figure 224. List of modified refractivity versus height for the radiosonde on 09/12/1991 at 11:53 PDT.

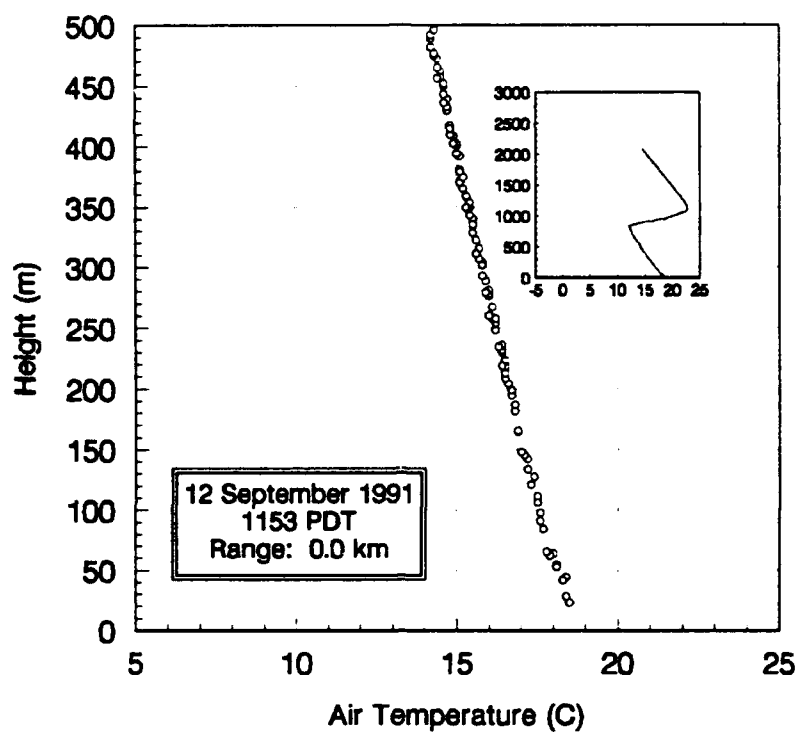


Figure 225. Relative humidity versus height for the radiosonde on 09/12/1991 at 11:53 PDT.

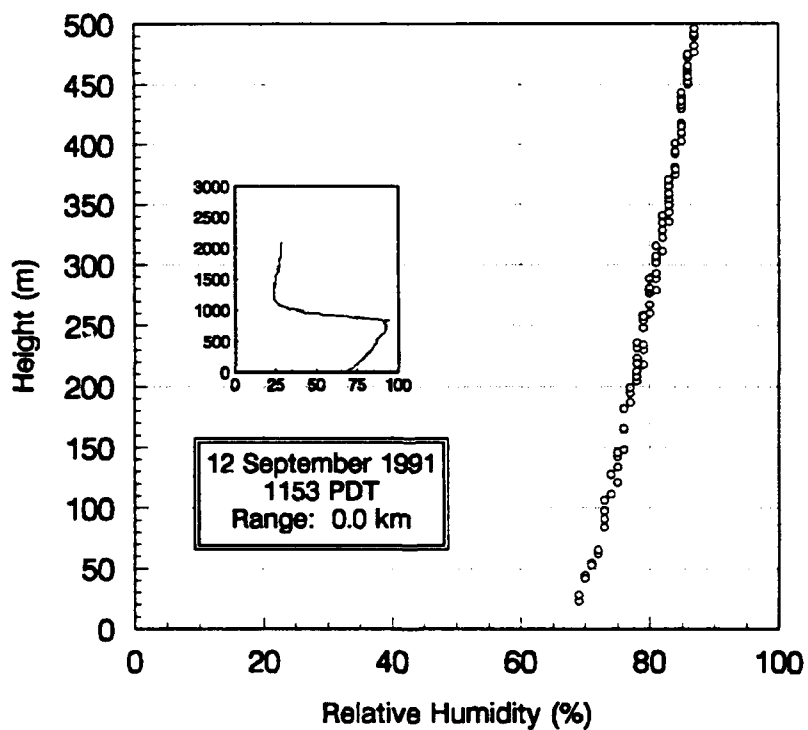


Figure 226. Air temperature versus height for the radiosonde on 09/12/1991 at 11:53 PDT.

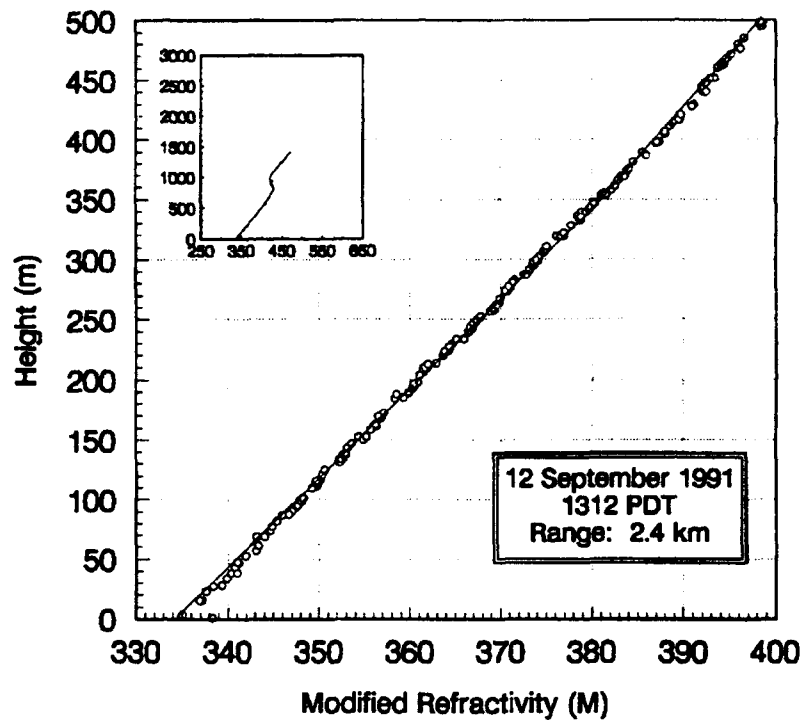


Figure 227. Modified refractivity versus height for the radiosonde on 09/12/1991 at 13:12 PDT.

Boat 2.4 km @ 268
Launch Height: 1 m

Height (m)	M-Units
0.00	334.21
347.67	380.83
494.62	397.67
681.00	419.92
813.62	430.75
956.99	419.62
1000.00	422.33

Figure 228. List of modified refractivity versus height for the radiosonde on 09/12/1991 at 13:12 PDT.

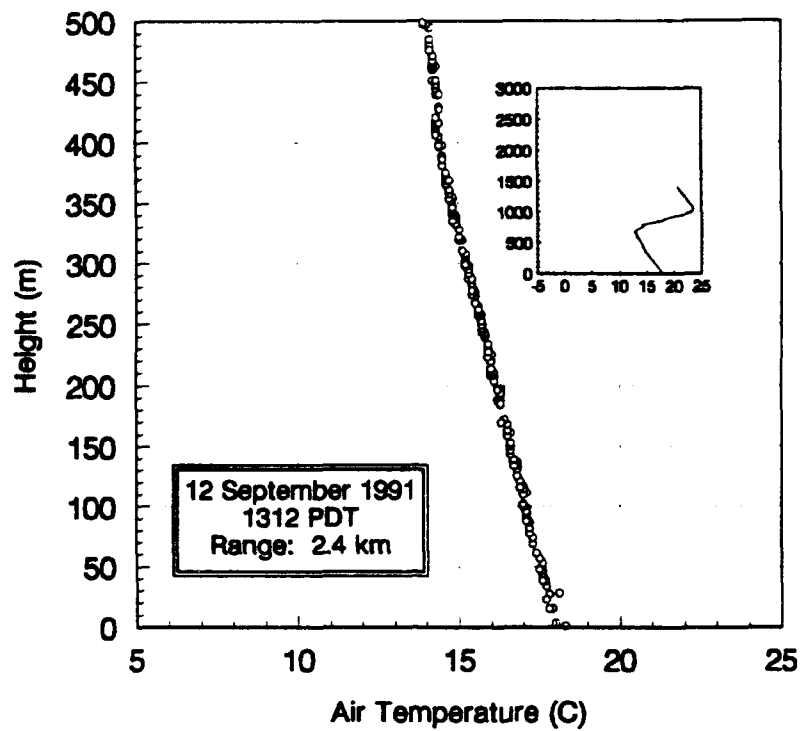


Figure 229. Relative humidity versus height for the radiosonde on 09/12/1991 at 13:12 PDT.

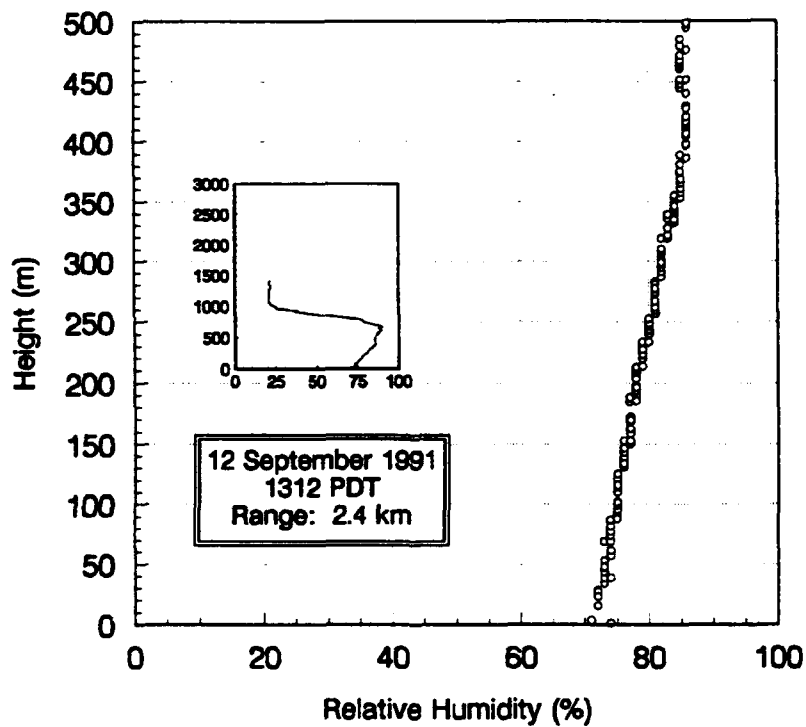


Figure 230. Air temperature versus height for the radiosonde on 09/12/1991 at 13:12 PDT.

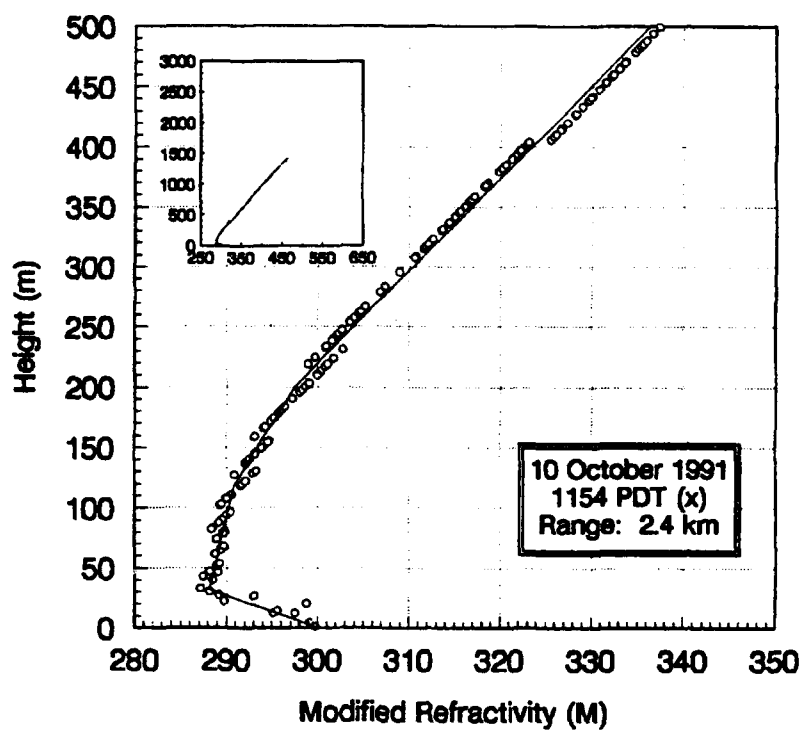


Figure 231. Modified refractivity versus height for the radiosonde on 10/10/1991 at 11:54 PDT.

Boat 2.4 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	300.15
32.26	288.12
118.28	290.83
200.72	297.44
989.25	400.00

Figure 232. List of modified refractivity versus height for the radiosonde on 10/10/1991 at 11:54 PDT.

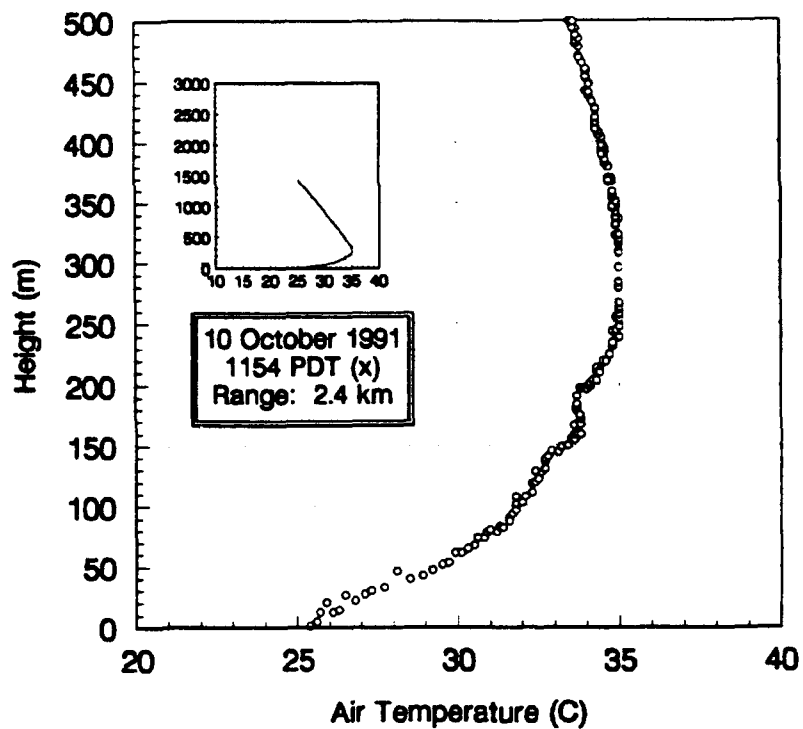


Figure 233. Relative humidity versus height for the radiosonde on 10/10/1991 at 11:54 PDT.

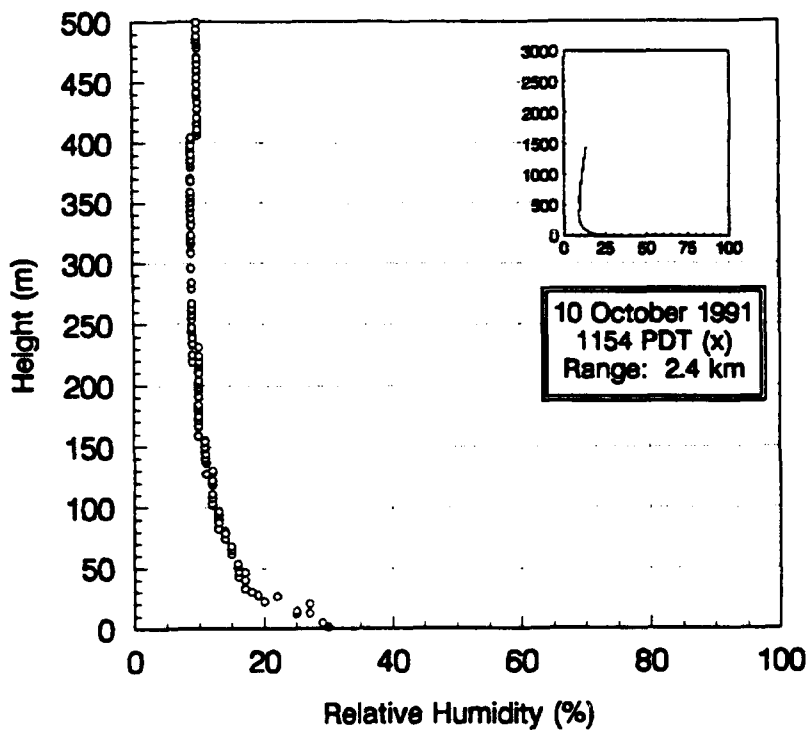


Figure 234. Air temperature versus height for the radiosonde on 10/10/1991 at 11:54 PDT.

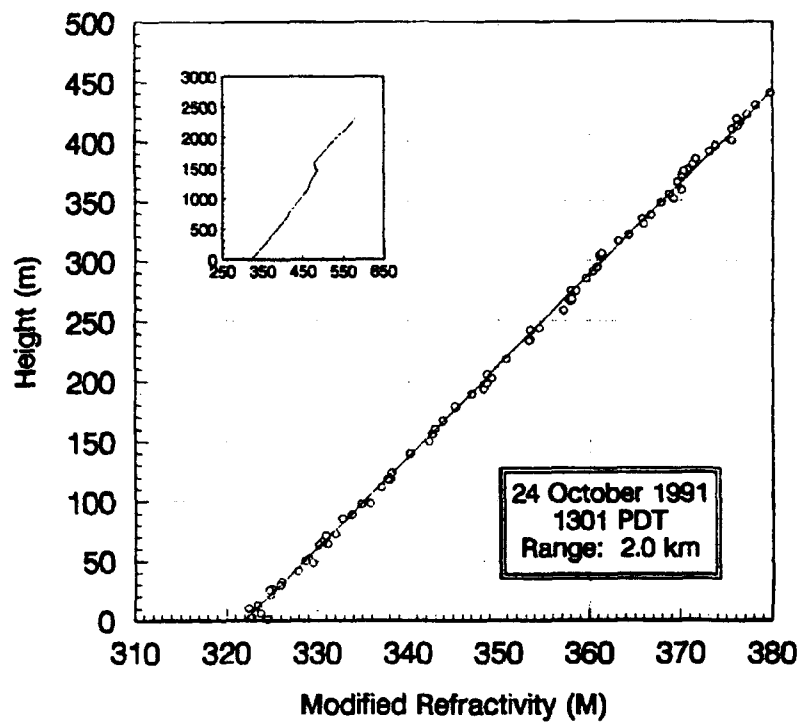


Figure 235. Modified refractivity versus height for the radiosonde on 10/24/1991 at 13:01 PDT.

Boat 2 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	321.92
408.60	375.75
709.68	413.05
738.35	412.44
921.15	435.00

Figure 236. List of modified refractivity versus height for the radiosonde on 10/24/1991 at 13:01 PDT.

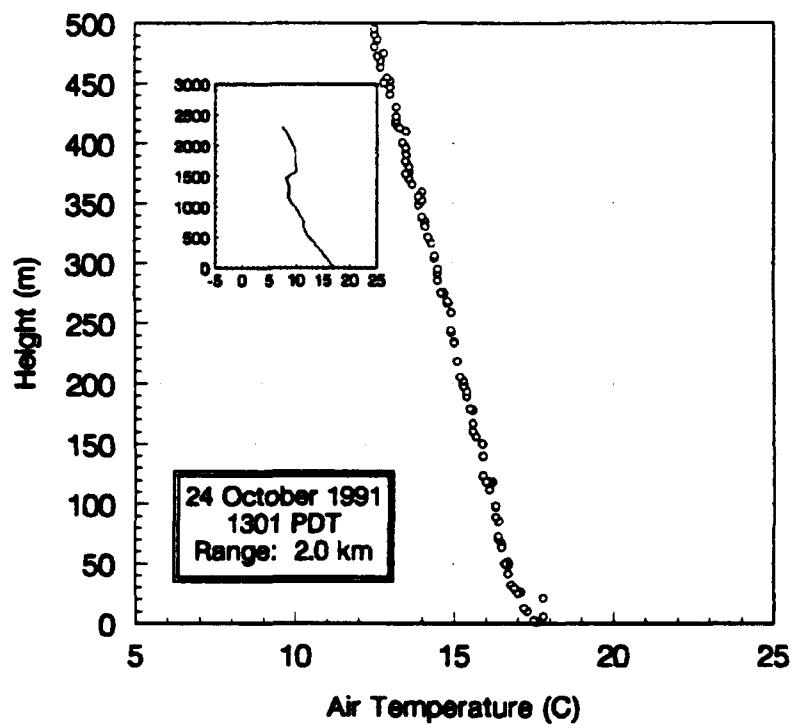


Figure 237. Relative humidity versus height for the radiosonde on 10/24/1991 at 13:01 PDT.

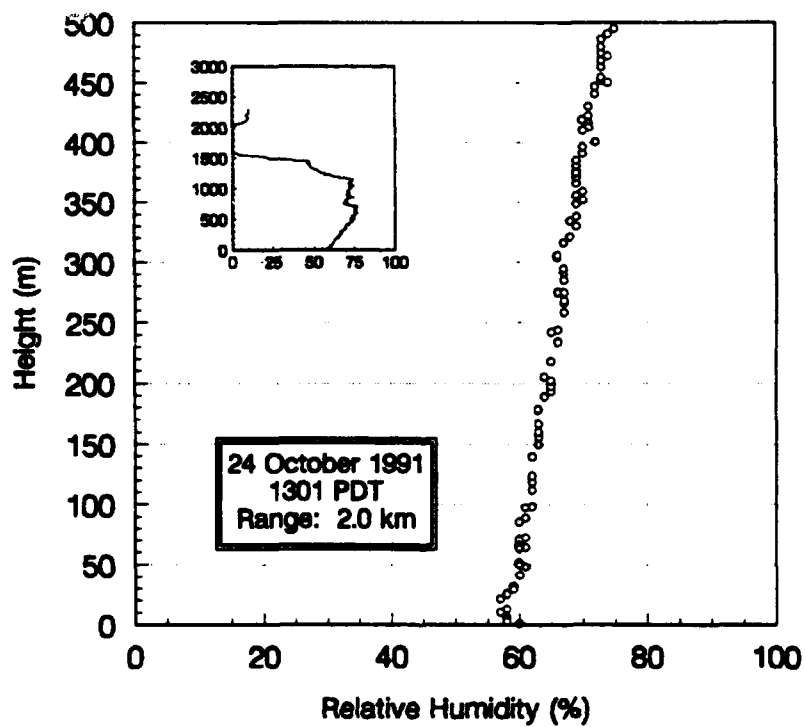


Figure 238. Air temperature versus height for the radiosonde on 10/24/1991 at 13:01 PDT.

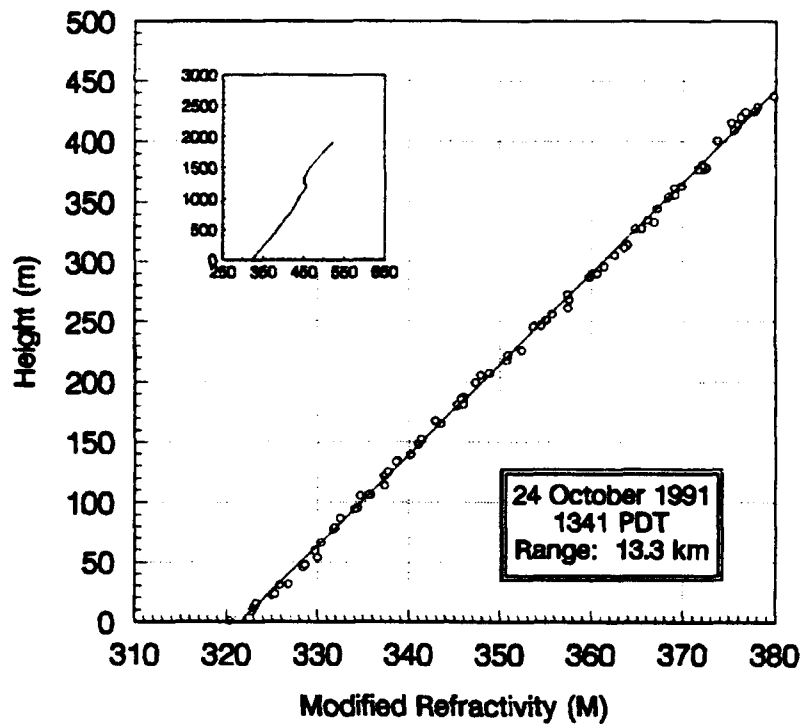


Figure 239. Modified refractivity versus height for the radiosonde on 10/24/1991 at 13:41 PDT.

Boat 13.3 km @ 269
Launch Height: 1 m

Height (m)	M-Units
0.00	321.54
247.31	354.32
455.20	381.69
476.70	381.09
630.82	400.64
645.16	400.64
695.34	406.35
756.27	416.28
860.22	425.00

Figure 240. List of modified refractivity versus height for the radiosonde on 10/24/1991 at 13:41 PDT.

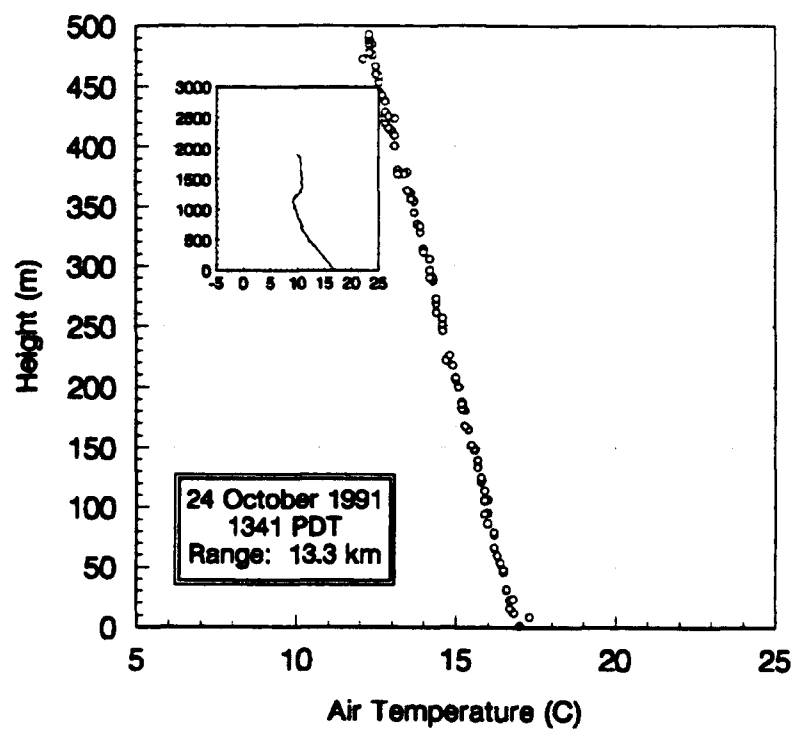


Figure 241. Relative humidity versus height for the radiosonde on 10/24/1991 at 13:41 PDT.

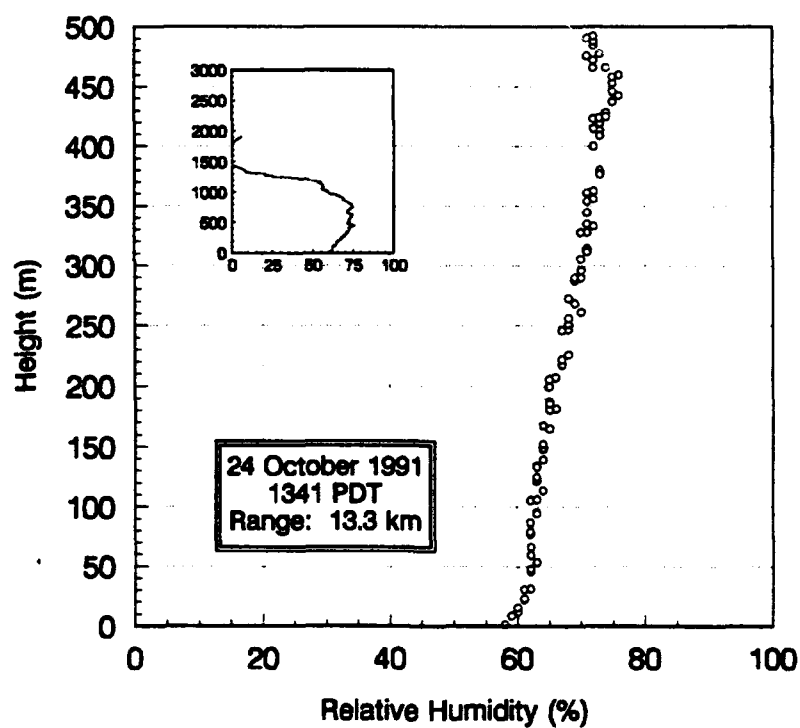


Figure 242. Air temperature versus height for the radiosonde on 10/24/1991 at 13:41 PDT.

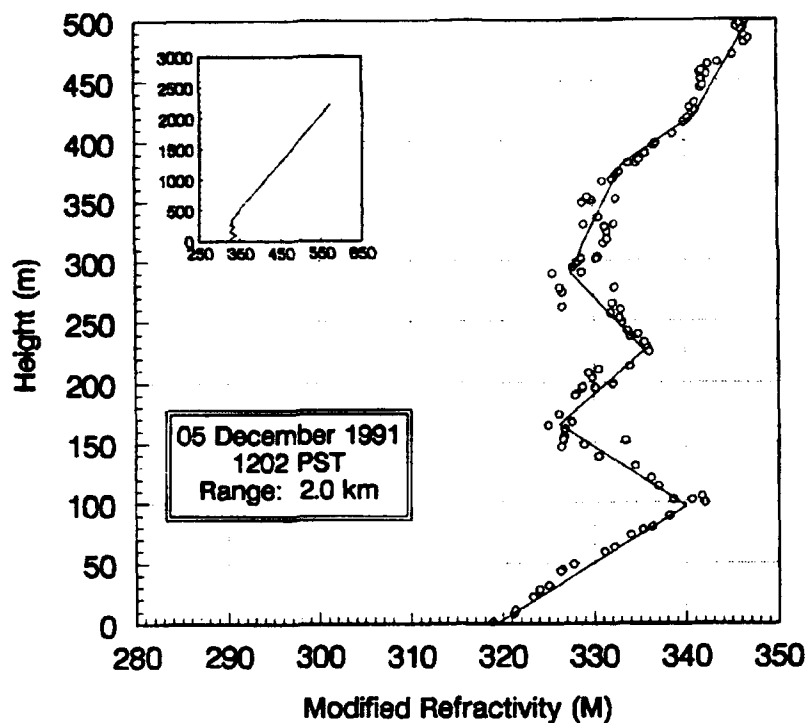


Figure 243. Modified refractivity versus height for the radiosonde on 12/05/1991 at 12:02 PST.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	319.32
96.77	340.08
164.87	326.24
225.81	335.56
290.32	327.44
379.93	333.16
422.94	341.28
548.39	350.60
1000.00	412.26

Figure 244. List of modified refractivity versus height for the radiosonde on 12/05/1991 at 12:02 PST.

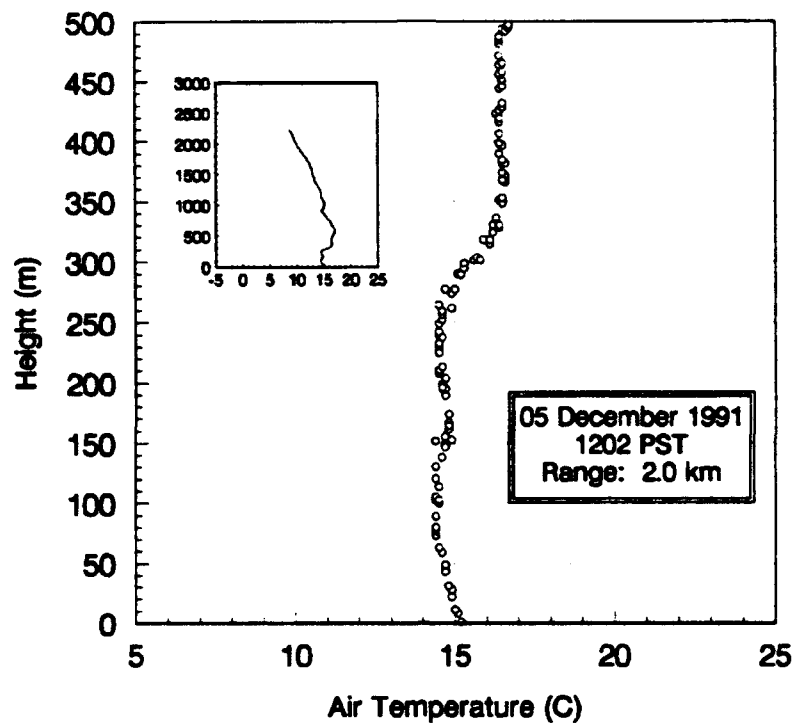


Figure 245. Relative humidity versus height for the radiosonde on 12/05/1991 at 12:02 PST.

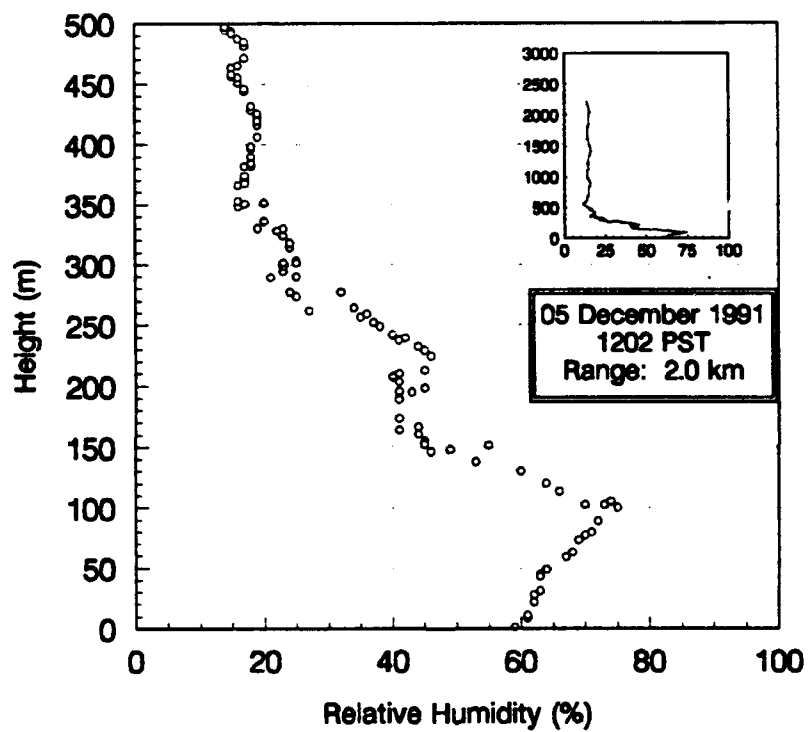


Figure 246. Air temperature versus height for the radiosonde on 12/05/1991 at 12:02 PST.

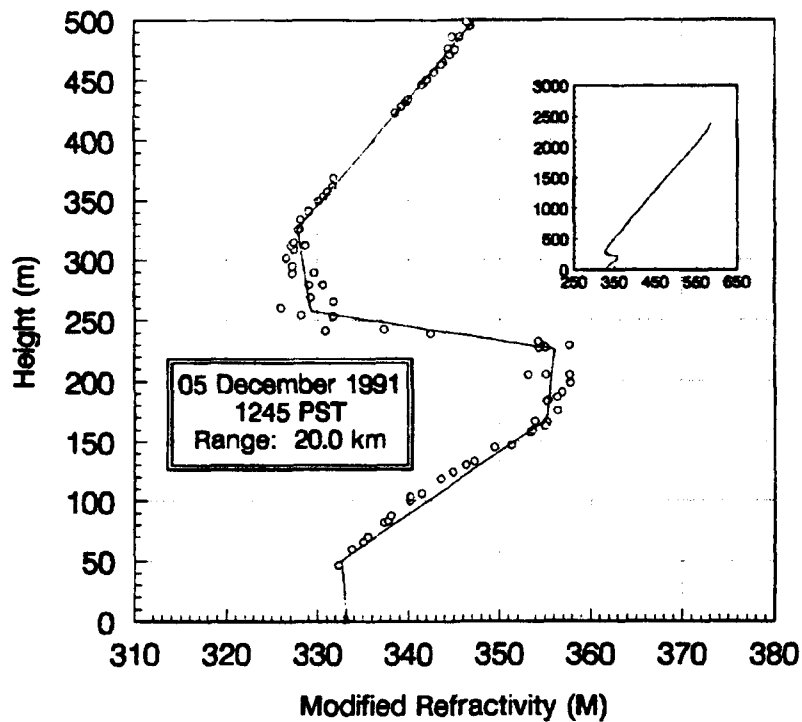


Figure 247. Modified refractivity versus height for the radiosonde on 12/05/1991 at 12:45 PST.

Boat 20.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	333.23
50.18	332.63
168.46	355.19
225.81	356.09
258.06	329.32
326.16	327.82
537.63	351.58
1000.00	413.23

Figure 248. List of modified refractivity versus height for the radiosonde on 12/05/1991 at 12:45 PST.

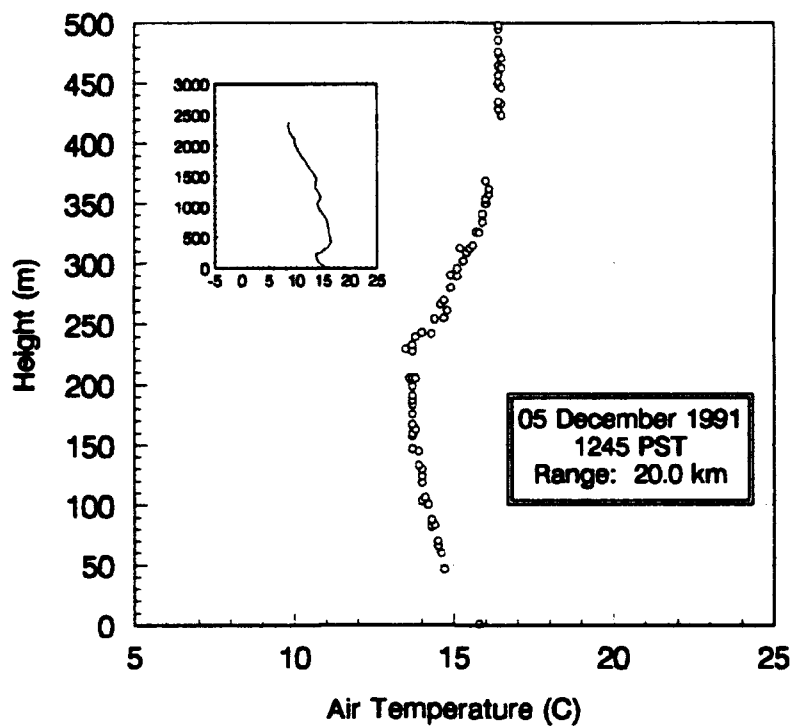


Figure 249. Relative humidity versus height for the radiosonde on 12/05/1991 at 12:45 PST.

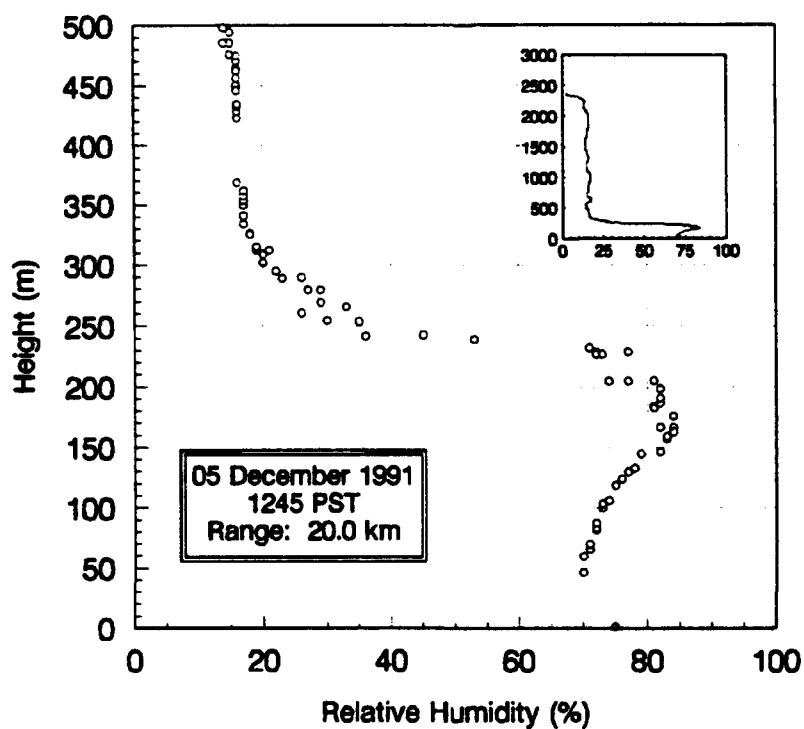


Figure 250. Air temperature versus height for the radiosonde on 12/05/1991 at 12:45 PST.

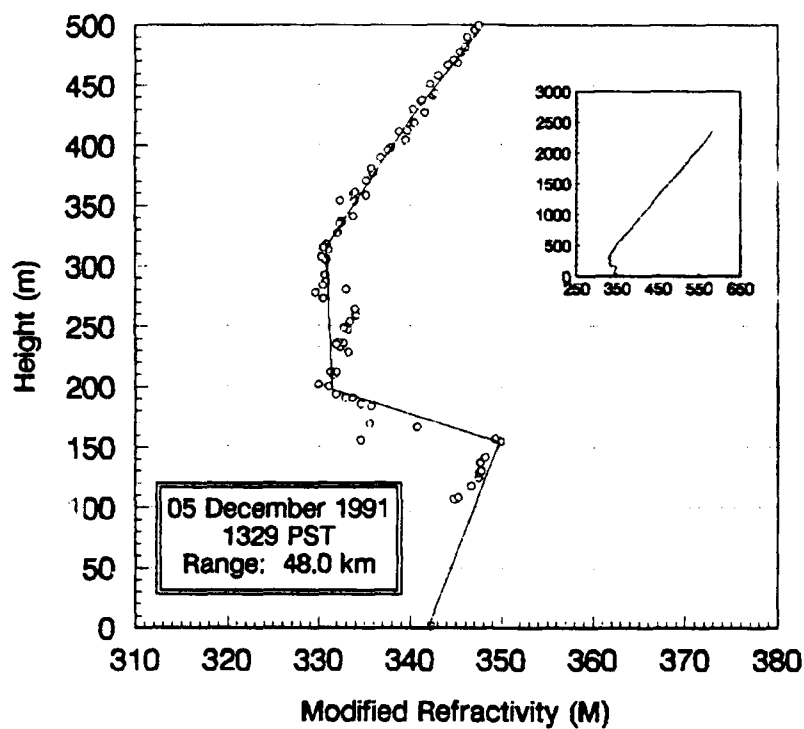


Figure 251. Modified refractivity versus height for the radiosonde on 12/05/1991 at 13:29 PST.

Boat 48.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	341.95
154.12	349.77
197.13	331.43
315.41	330.83
422.94	340.15
584.23	356.69
1000.00	412.33

Figure 252. List of modified refractivity versus height for the radiosonde on 12/05/1991 at 13:29 PST.

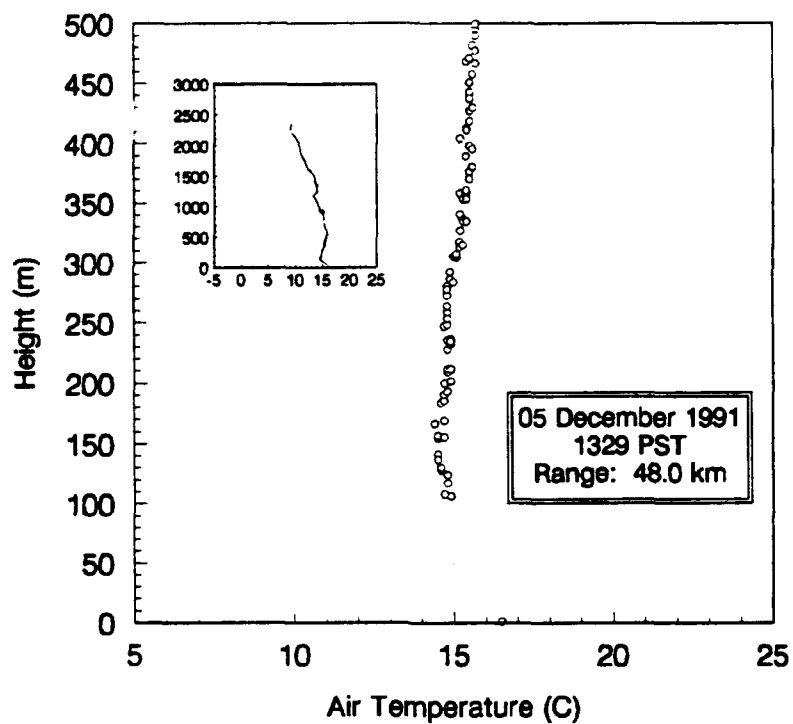


Figure 253. Relative humidity versus height for the radiosonde on 12/05/1991 at 13:29 PST.

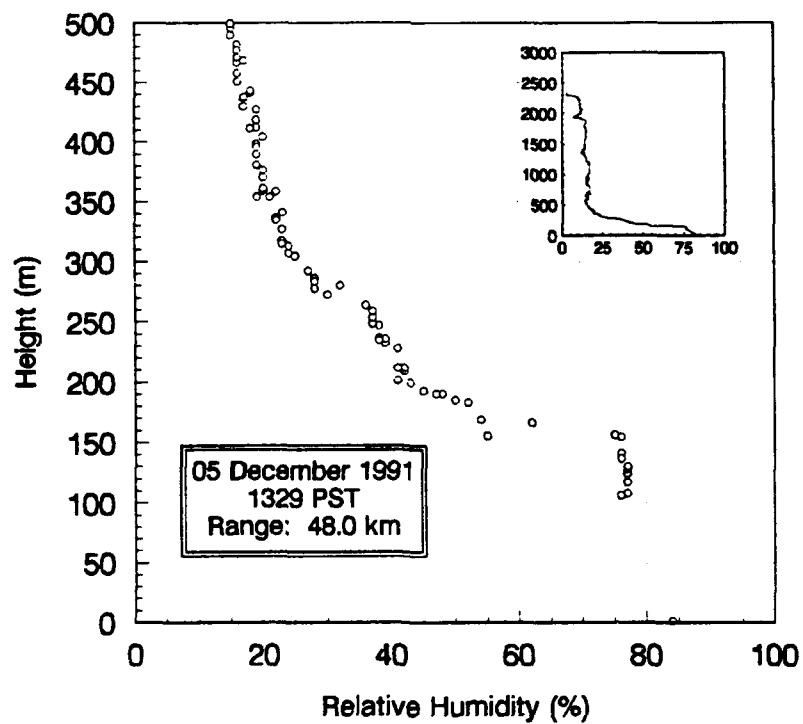


Figure 254. Air temperature versus height for the radiosonde on 12/05/1991 at 13:29 PST.

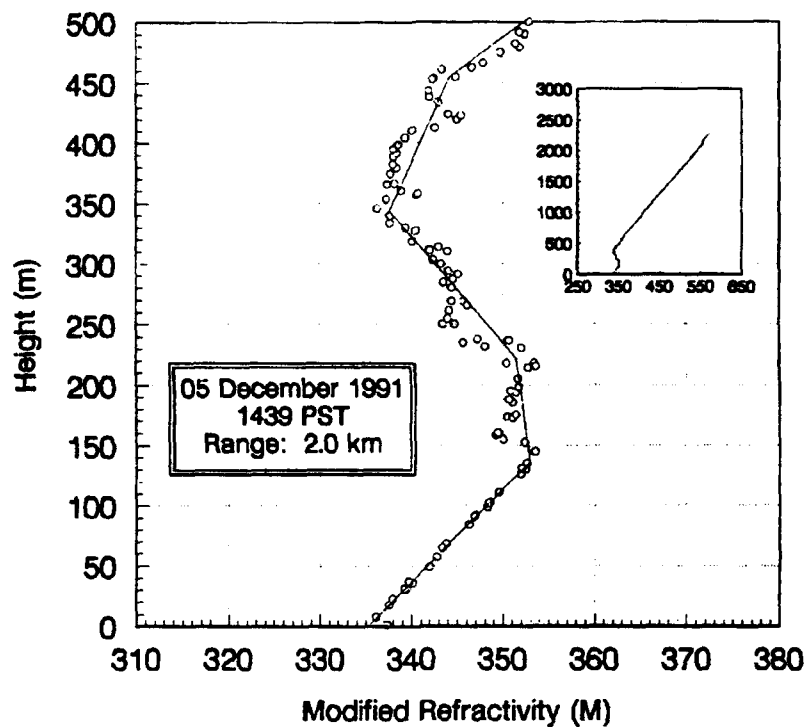


Figure 255. Modified refractivity versus height for the radiosonde on 12/05/1991 at 14:39 PST.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	335.23
136.20	352.97
222.22	351.47
344.09	337.63
455.20	344.25
508.96	353.87
652.33	366.50
1000.00	412.22

Figure 256. List of modified refractivity versus height for the radiosonde on 12/05/1991 at 14:39 PST.

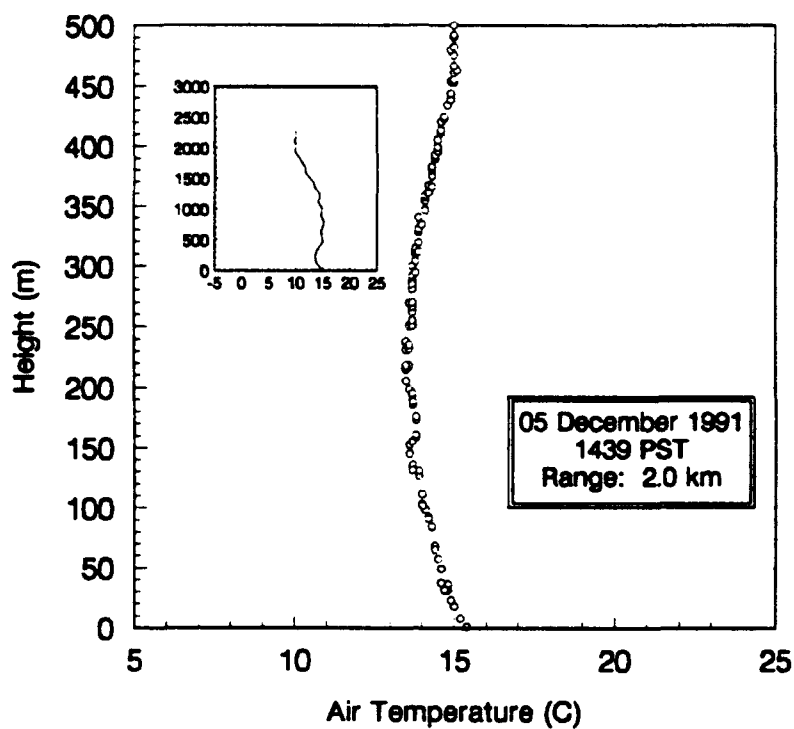


Figure 257. Relative humidity versus height for the radiosonde on 12/05/1991 at 14:39 PST.

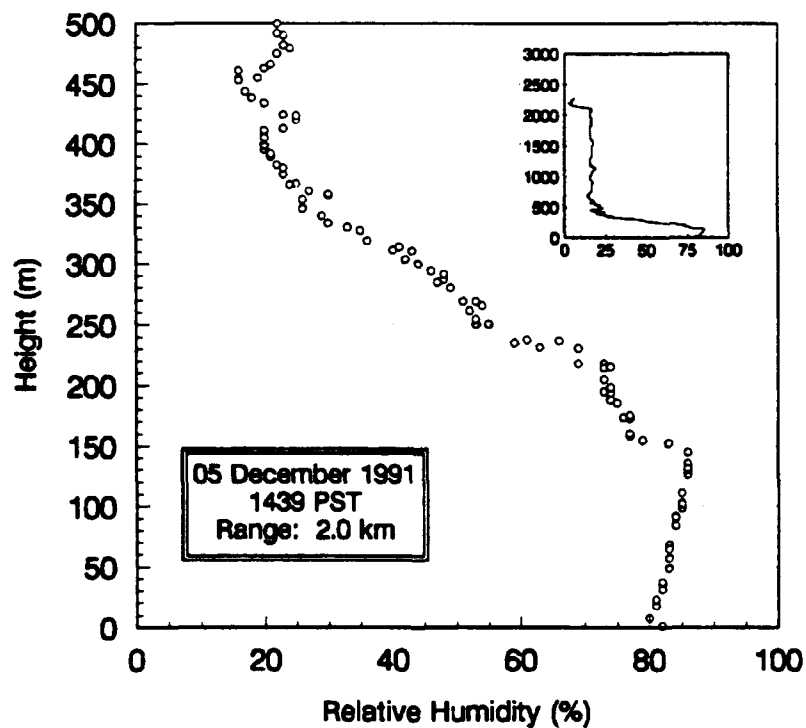


Figure 258. Air temperature versus height for the radiosonde on 12/05/1991 at 14:39 PST.

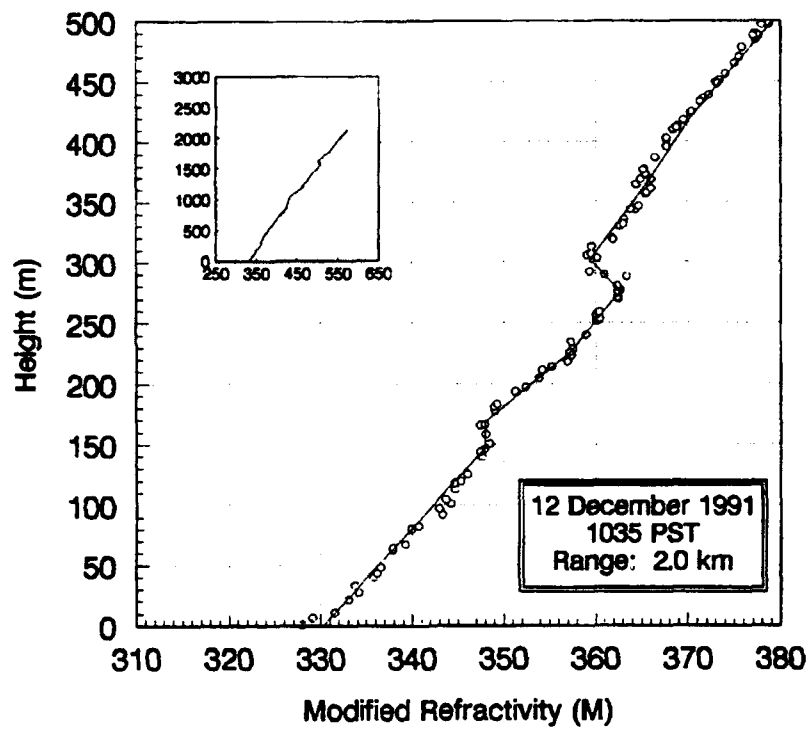


Figure 259. Modified refractivity versus height for the radiosonde on 12/12/1991 at 10:35 PST.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	330.23
146.95	347.97
168.46	347.97
225.81	357.29
275.99	362.71
301.08	359.40
369.18	366.02
422.94	370.53
602.15	390.68
716.85	403.61
842.29	420.75
1000.00	429.47

Figure 260. List of modified refractivity versus height for the radiosonde on 12/12/1991 at 10:35 PST.

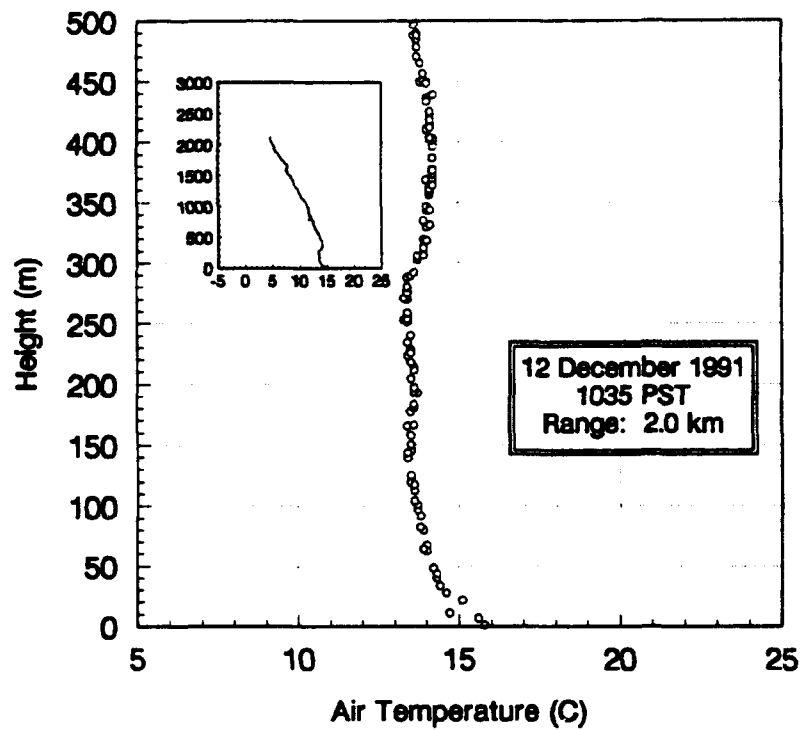


Figure 261. Relative humidity versus height for the radiosonde on 12/12/1991 at 10:35 PST.

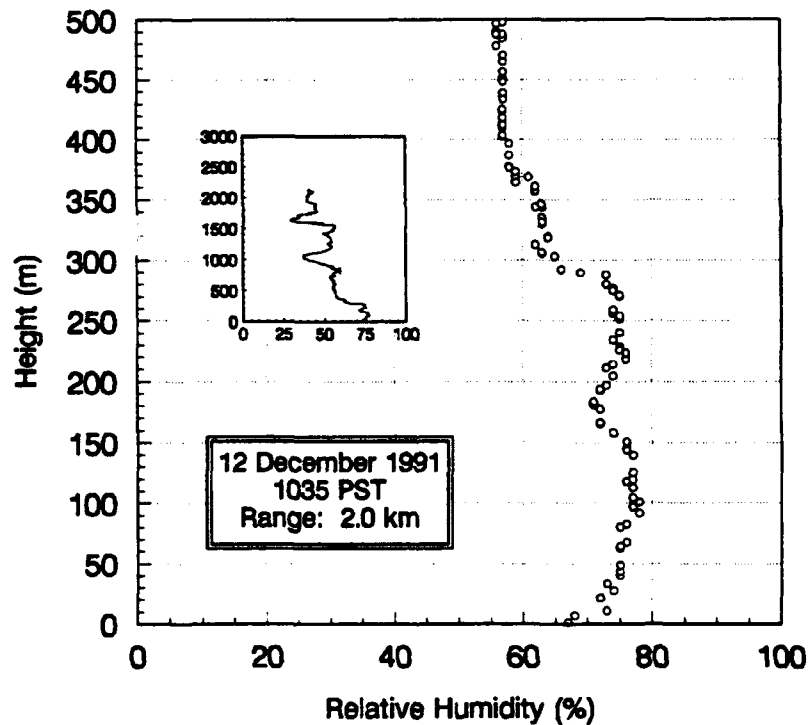


Figure 262. Air temperature versus height for the radiosonde on 12/12/1991 at 10:35 PST.

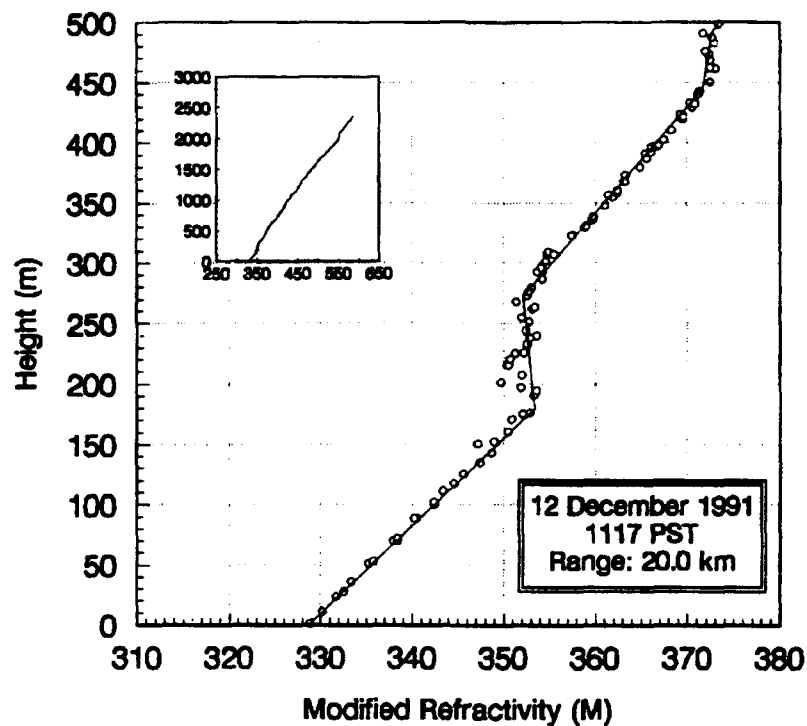


Figure 263. Modified refractivity versus height for the radiosonde on 12/12/1991 at 11:17 PST.

Boat 20.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	328.72
179.21	353.38
272.40	352.18
444.44	371.73
491.04	372.63
641.58	387.97
670.25	396.39
1000.00	426.77

Figure 264. List of modified refractivity versus height for the radiosonde on 12/12/1991 at 11:17 PST.

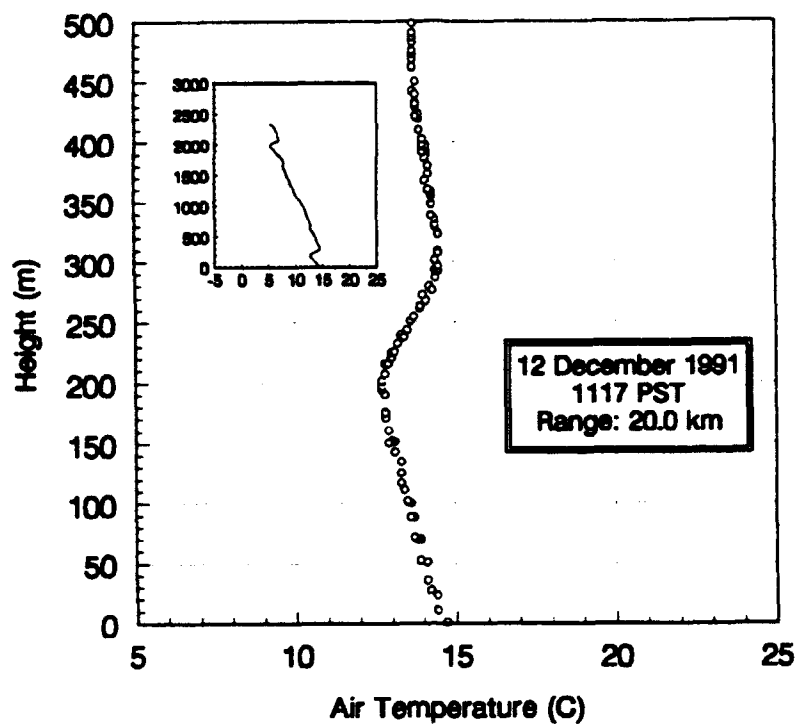


Figure 265. Relative humidity versus height for the radiosonde on 12/12/1991 at 11:17 PST.

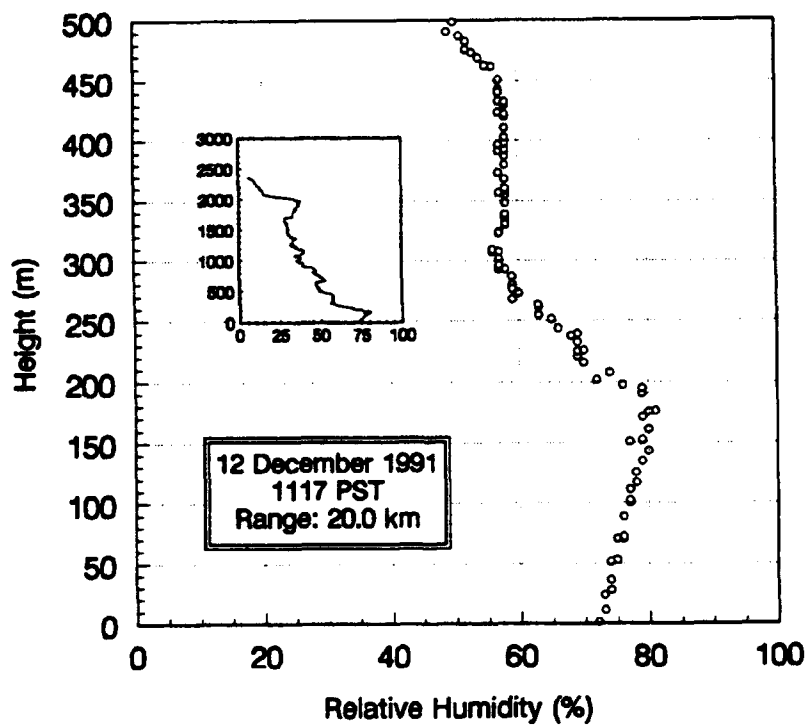


Figure 266. Air temperature versus height for the radiosonde on 12/12/1991 at 11:17 PST.

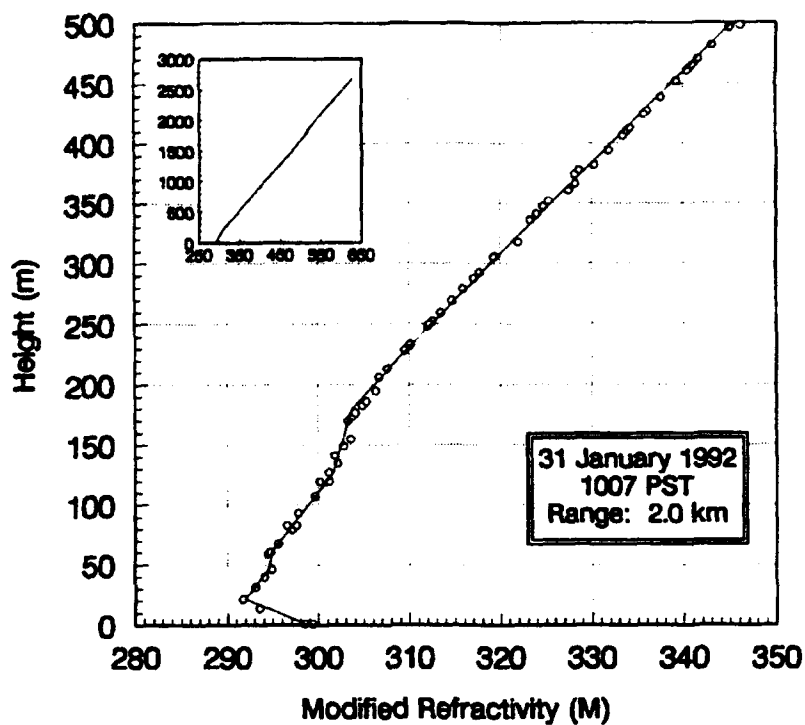


Figure 267. Modified refractivity versus height for the radiosonde on 01/31/1992 at 10:07 PST.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	298.83
21.51	291.92
46.59	294.62
60.93	294.92
125.45	301.54
179.21	303.65
232.97	310.26
347.67	325.30
956.99	405.00

Figure 268. List of modified refractivity versus height for the radiosonde on 01/31/1992 at 10:07 PST.

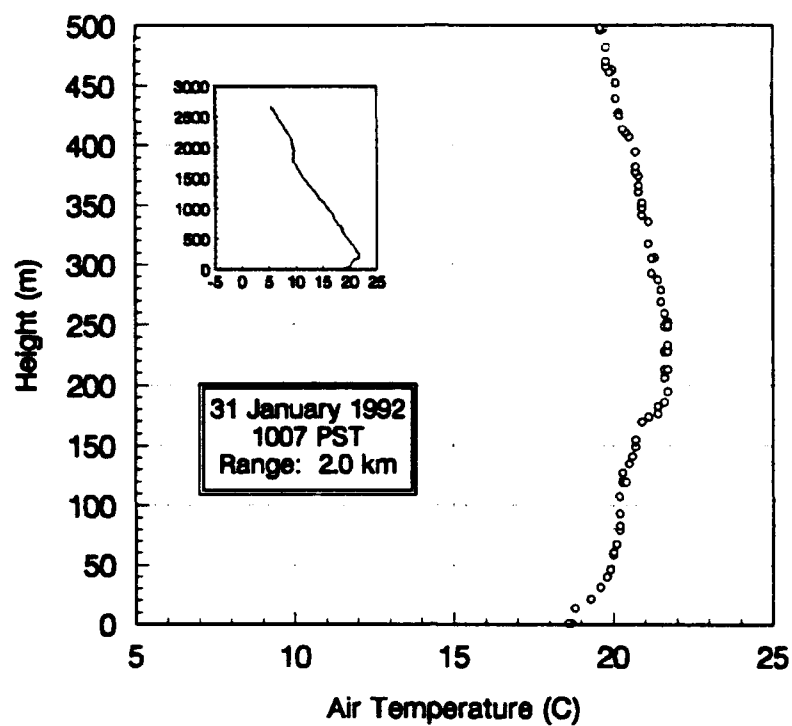


Figure 269. Relative humidity versus height for the radiosonde on 01/31/1992 at 10:07 PST.

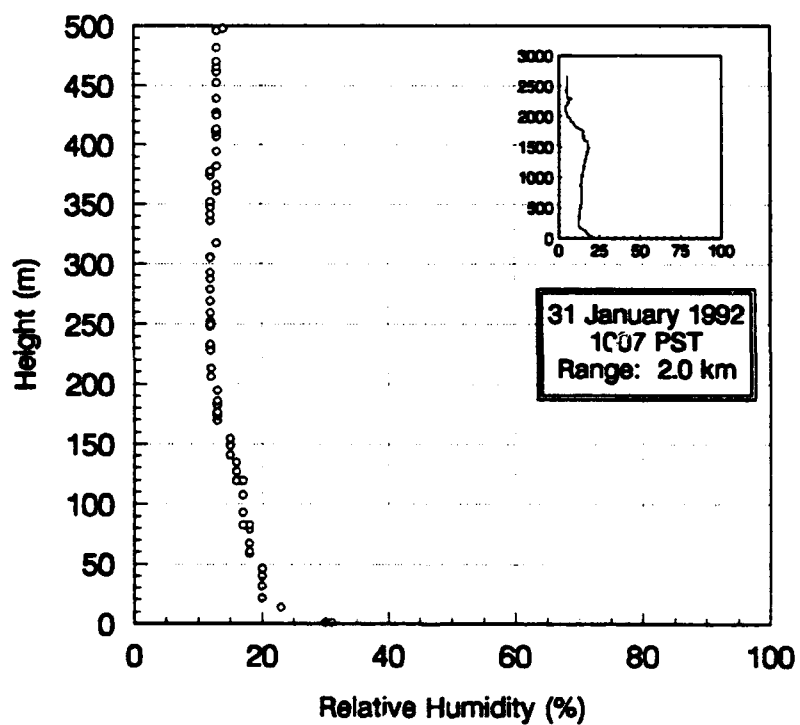


Figure 270. Air temperature versus height for the radiosonde on 01/31/1992 at 10:07 PST.

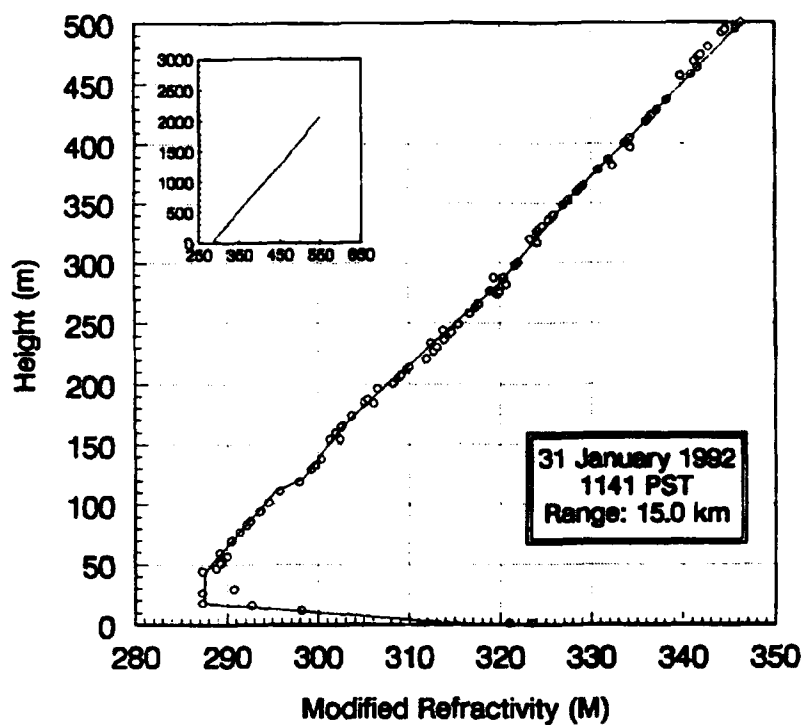


Figure 271. Modified refractivity versus height for the radiosonde on 01/31/1992 at 11:40 PST.

Boat 15 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	317.29
17.92	287.52
43.01	287.52
111.11	295.34
121.86	298.35
161.29	302.26
200.72	307.67
283.15	320.00
354.84	327.82
917.56	400.00

Figure 272. List of modified refractivity versus height for the radiosonde on 01/31/1992 at 11:40 PST.

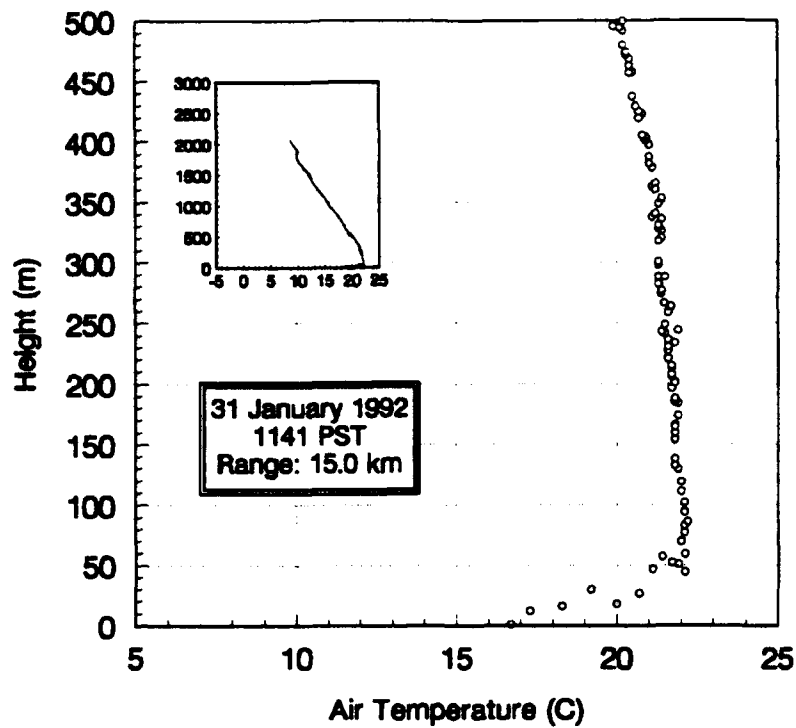


Figure 273. Relative humidity versus height for the radiosonde on 01/31/1992 at 11:40 PST.

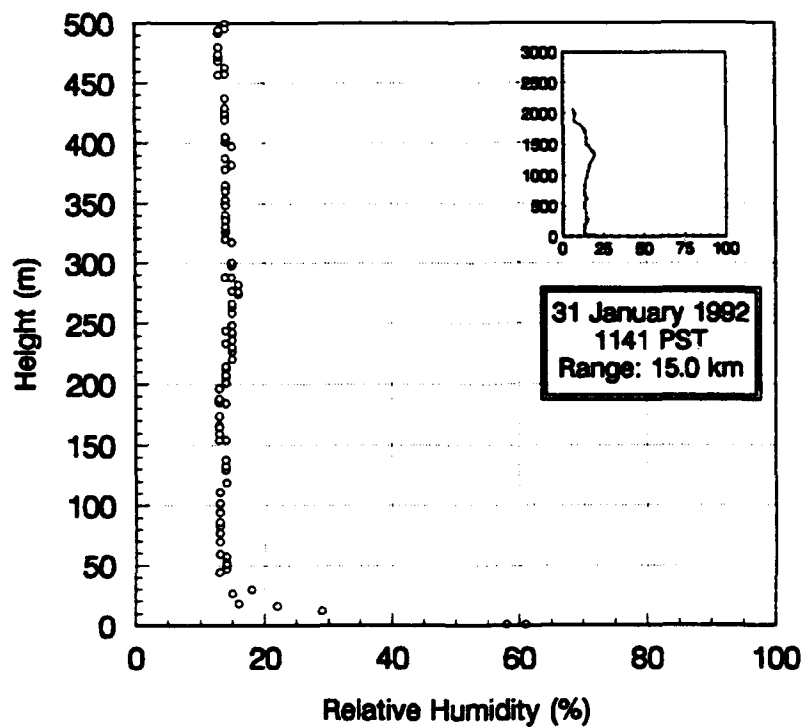


Figure 274. Air temperature versus height for the radiosonde on 01/31/1992 at 11:40 PST.

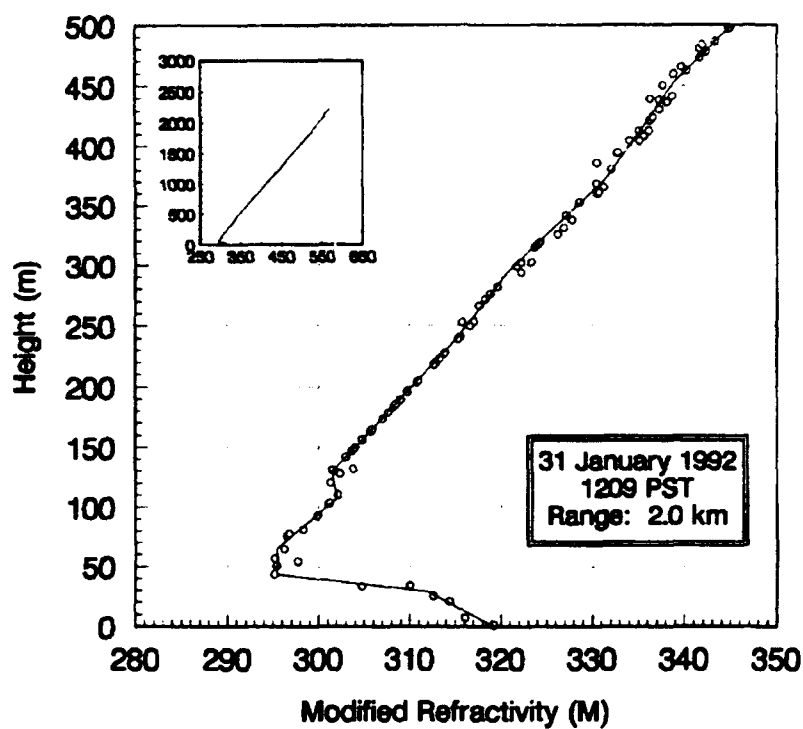


Figure 275. Modified refractivity versus height for the radiosonde on 01/31/1992 at 12:09 PST.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	319.17
28.67	311.95
43.01	295.41
64.52	295.41
107.53	302.03
129.03	301.43
240.14	315.26
293.91	320.68
372.76	331.50
372.76	331.50
372.76	331.50
451.61	338.72
989.25	410.00

Figure 276. List of modified refractivity versus height for the radiosonde on 01/31/1992 at 12:09 PST.

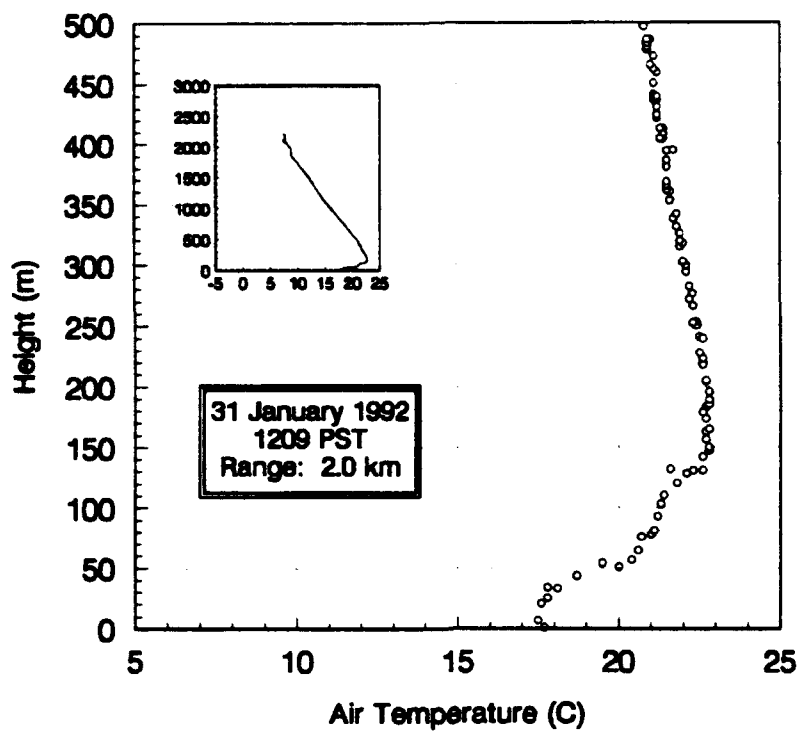


Figure 277. Relative humidity versus height for the radiosonde on 01/31/1992 at 12:09 PST.

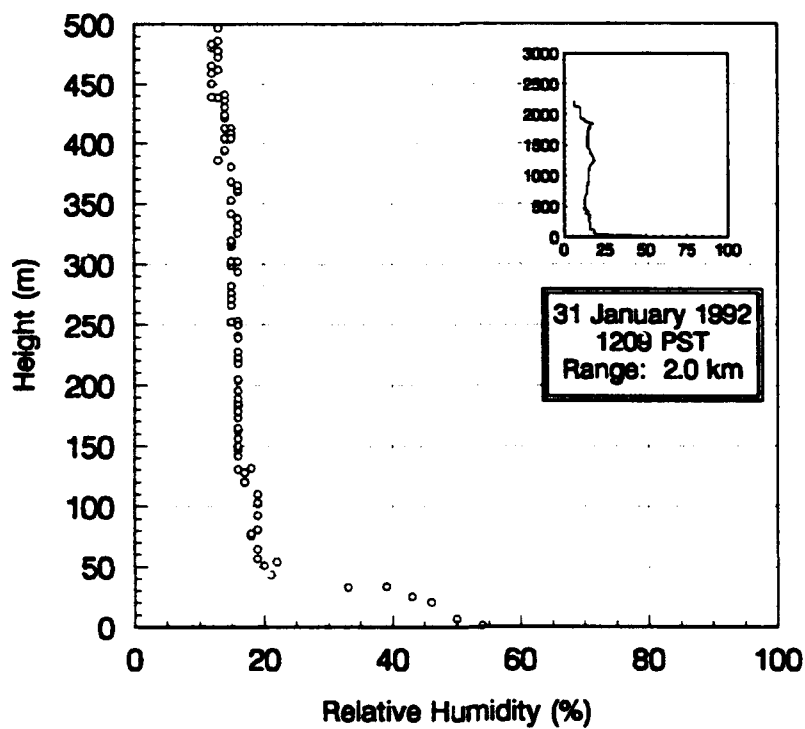


Figure 278. Air temperature versus height for the radiosonde on 01/31/1992 at 12:09 PST.

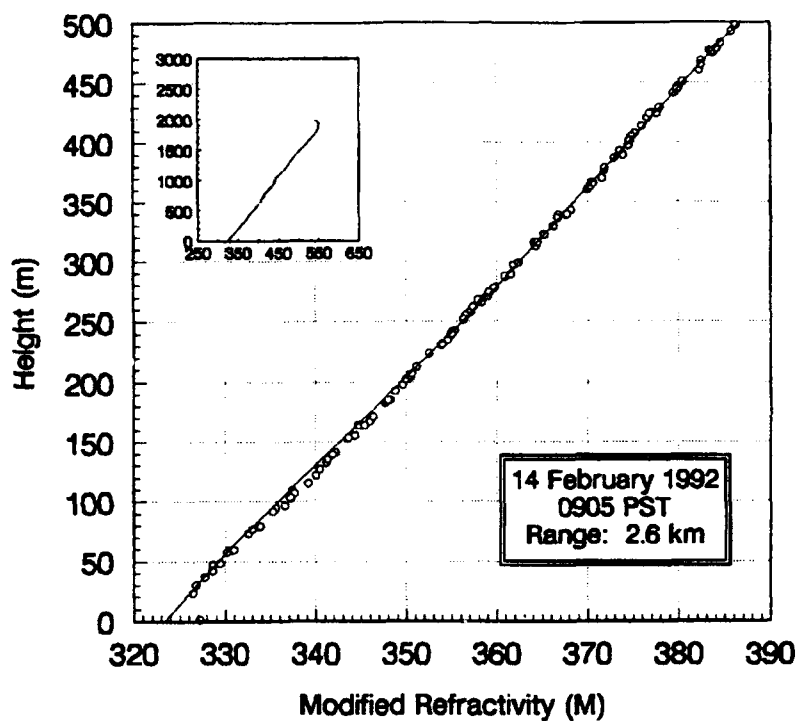


Figure 279. Modified refractivity versus height for the radiosonde on 02/14/1992 at 09:05 PST.

Boat 2.6 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	323.27
64.52	331.09
275.99	359.66
483.87	384.62
659.50	407.78
670.25	406.88
745.52	415.00

Figure 280. List of modified refractivity versus height for the radiosonde on 02/14/1992 at 09:05 PST.

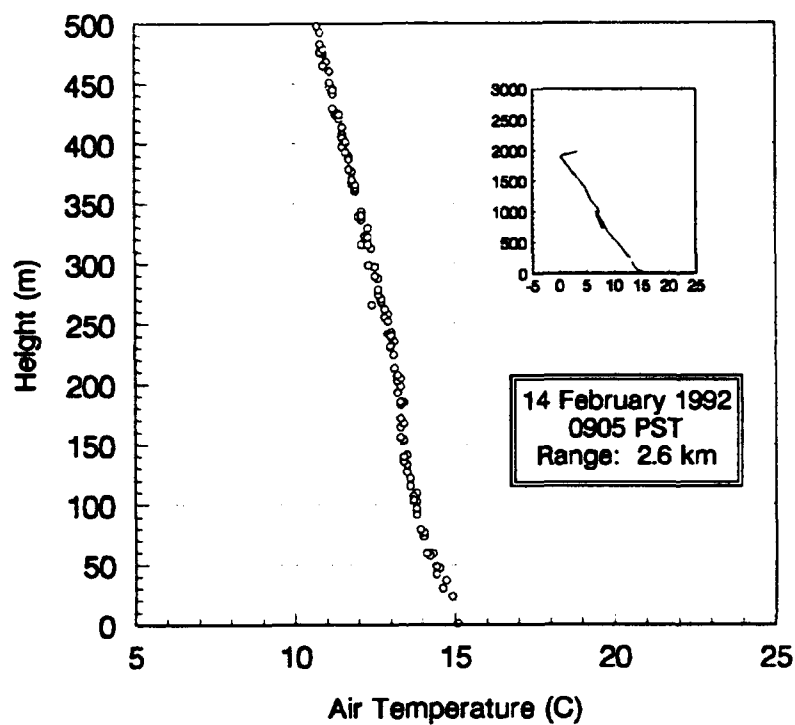


Figure 281. Relative humidity versus height for the radiosonde on 02/14/1992 at 09:05 PST.

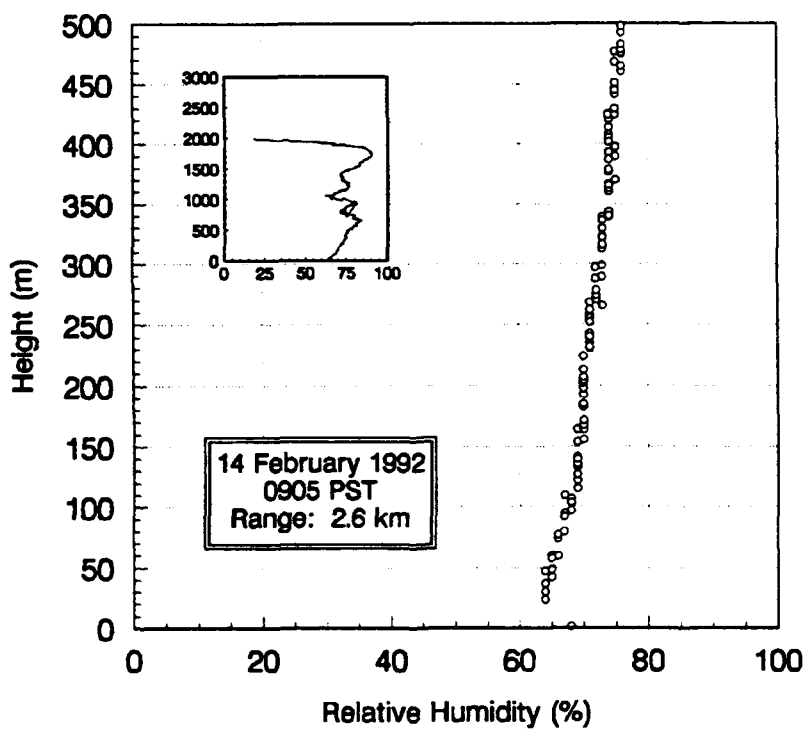


Figure 282. Air temperature versus height for the radiosonde on 02/14/1992 at 09:05 PST.

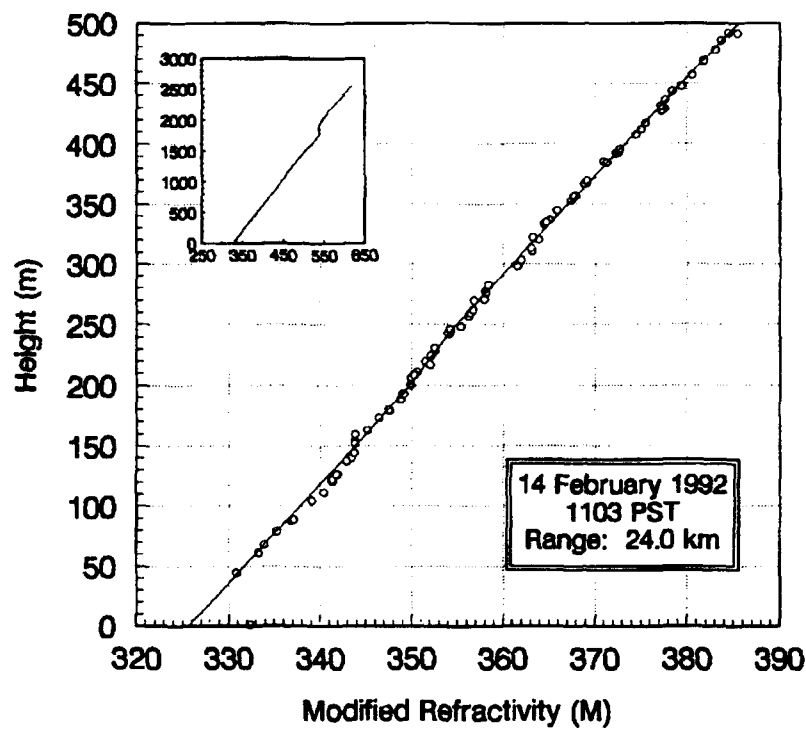


Figure 283. Modified refractivity versus height for the radiosonde on 02/14/1992 at 11:03 PST.

Boat 24.0 km @ 272
Launch Height: 1 m

Height (m)	M-Units
0.00	325.68
193.55	349.14
247.31	354.55
738.35	414.70

Figure 284. List of modified refractivity versus height for the radiosonde on 02/14/1992 at 11:03 PST.

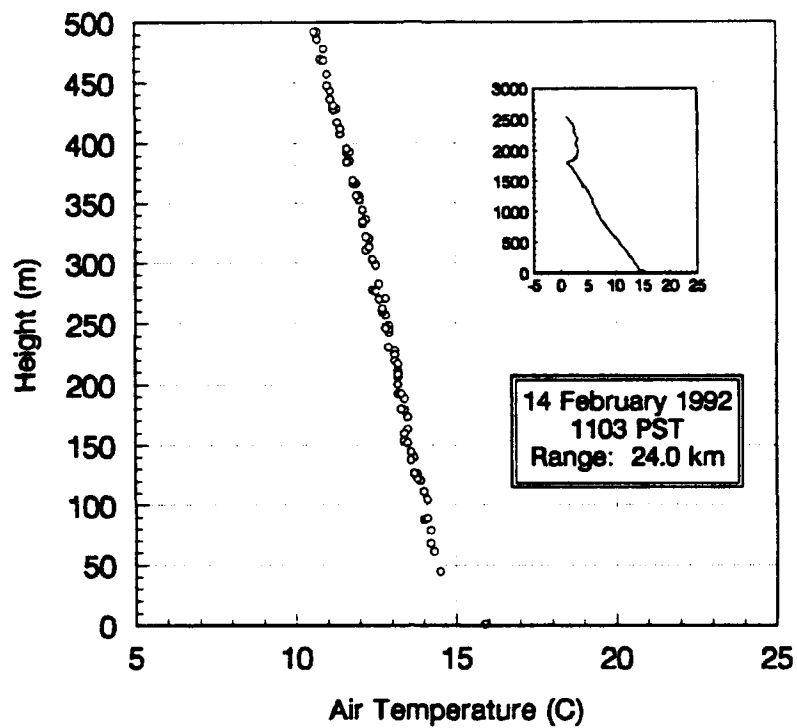


Figure 285. Relative humidity versus height for the radiosonde on 02/14/1992 at 11:03 PST.

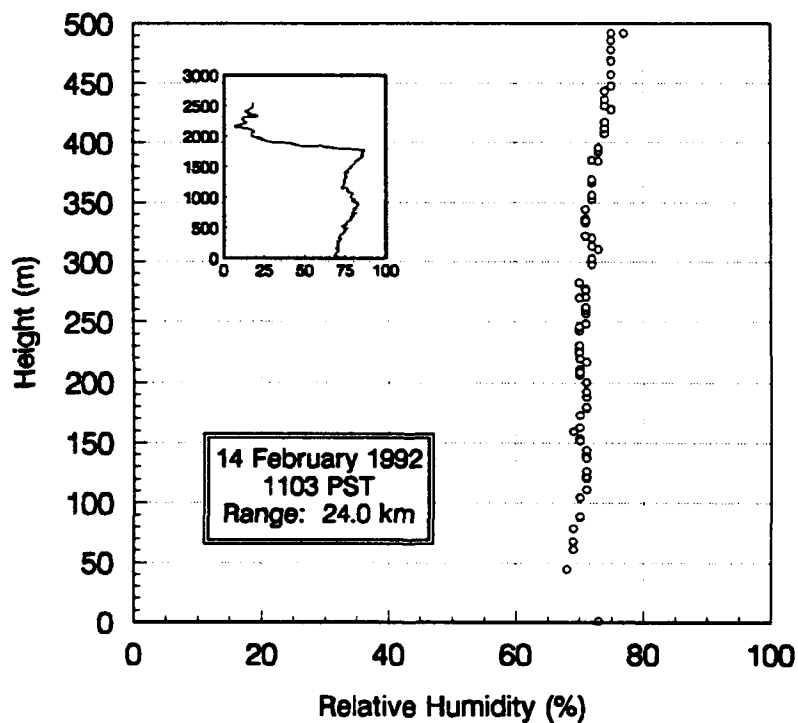


Figure 286. Air temperature versus height for the radiosonde on 02/14/1992 at 11:03 PST.

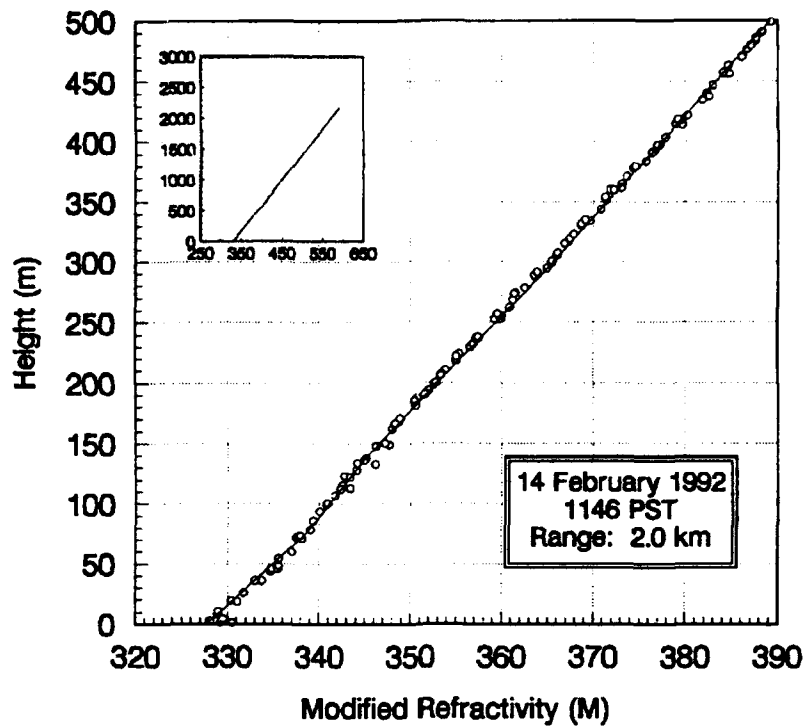


Figure 287. Modified refractivity versus height for the radiosonde on 02/14/1992 at 11:46 PST.

Boat 2.0 km @ 270
Launch Height: 1 m

Height (m)	M-Units
0.00	327.78
75.27	338.61
139.78	345.23
290.32	364.47
512.54	390.64
526.88	395.45
684.59	415.00

Figure 288. List of modified refractivity versus height for the radiosonde on 02/14/1992 at 11:46 PST.

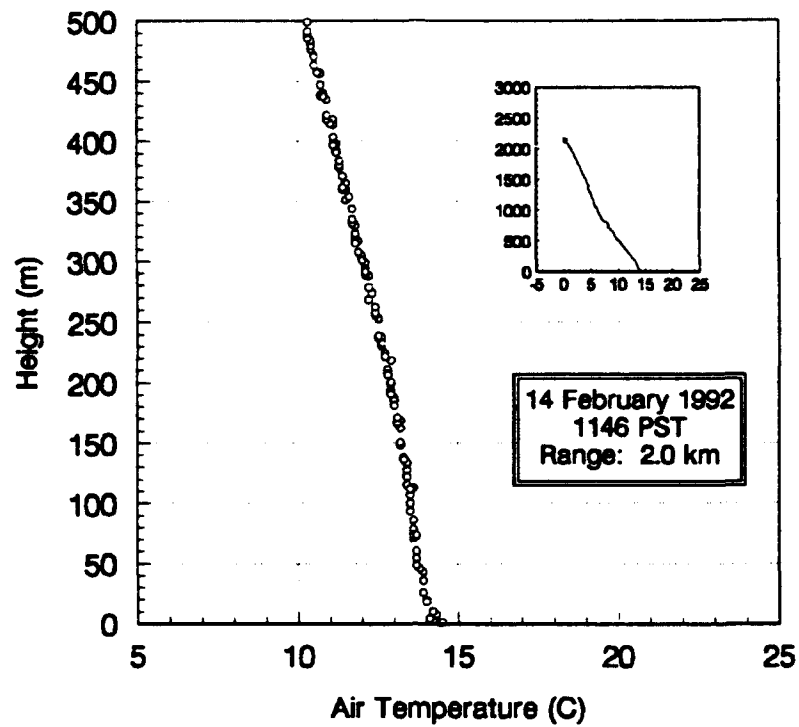


Figure 289. Relative humidity versus height for the radiosonde on 02/14/1992 at 11:46 PST.

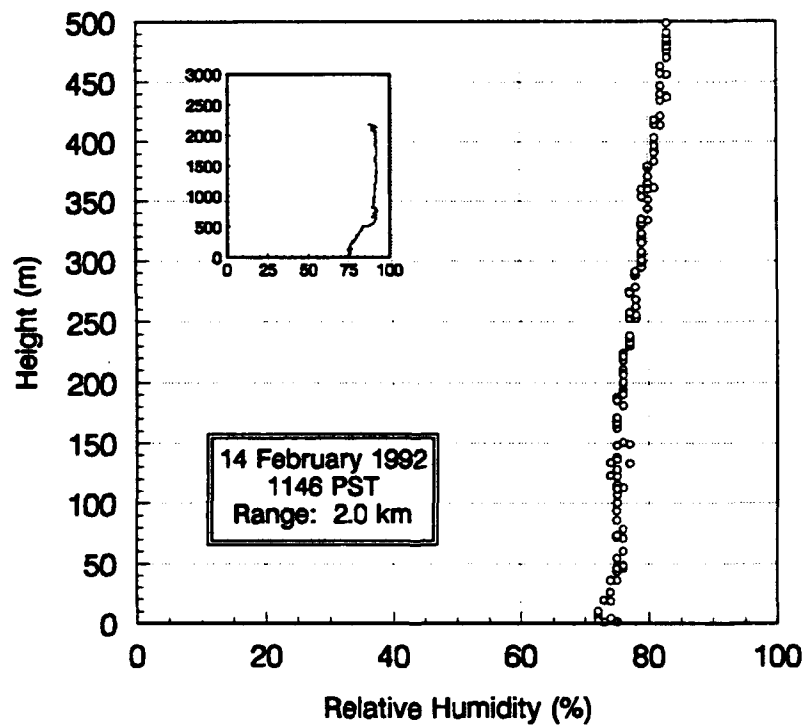


Figure 290. Air temperature versus height for the radiosonde on 02/14/1992 at 11:46 PST.

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